Transparent Ready
User Guide

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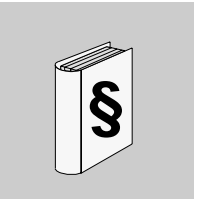
Safety Information



Important Information

NOTICE

Read these instructions carefully, and look at the equipment to become familiar with the device before trying to install, operate, or maintain it. The following special messages may appear throughout this documentation or on the equipment to warn of potential hazards or to call attention to information that clarifies or simplifies a procedure.

The addition of this symbol to a Danger or Warning safety label indicates that an electrical hazard exists, which will result in personal injury if the instructions are not followed.

This is the safety alert symbol. It is used to alert you to potential personal injury hazards. Obey all safety messages that follow this symbol to avoid possible injury or death.

⚠ DANGER

DANGER indicates an imminently hazardous situation, which, if not avoided, **will result** in death or serious injury.

⚠ WARNING

WARNING indicates a potentially hazardous situation, which, if not avoided, **can result** in death, serious injury, or equipment damage.

⚠ CAUTION

CAUTION indicates a potentially hazardous situation, which, if not avoided, **can result** in injury or equipment damage.

PLEASE NOTE

Electrical equipment should be installed, operated, serviced, and maintained only by qualified personnel. No responsibility is assumed by Schneider Electric for any consequences arising out of the use of this material.

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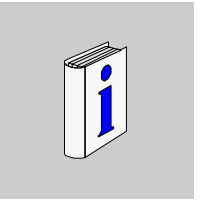
About the Book



At a Glance

Document Scope

This user guide deals with the broad topic of industrial Ethernet, a key element of Schneider Electric's *Transparent Ready* strategy. The purposes of the guide are twofold:

- to describe the impact of industrial Ethernet on new control system designs
- to give you the information you need to implement and support a Transparent Ready solution that best meets your application requirements

The guide describes four key parts of a successful system implementation:

- planning a system for optimal performance
- selecting the right Ethernet services and devices for your application
- making the right choices as you design and install the system
- troubleshooting system problems effectively

The guide is written for:

- design engineers, system integrators and maintenance engineers who understand industrial control systems and requirements but may not be familiar with Ethernet products and services
- plant IT staff who understand the principles of Ethernet system design and installation but may not be familiar with industrial control requirements and environments

Ethernet technology is well established in the business and commercial worlds, but it is relatively new to the automation industry. Because it is an open technology, Ethernet offers a wide range of products and services from multiple vendors. The advantages of an open approach are clear; you are no longer subject to the communication constraints, costs, and development schedules of a proprietary vendor for your system needs.

However, some Ethernet components may not interoperate optimally in an industrial environment, and not all Ethernet devices support all the services you may want. To successfully design and troubleshoot an industrial Ethernet system, you need a mix of Ethernet IT and traditional automation knowledge. This guide is designed to help bridge the gap between these two disciplines.

The guide should be used as a supplement to product-specific Transparent Ready user manuals. To learn more about commercially available Transparent Ready products, refer to the latest Transparent Ready catalog or go to www.telemecanique.com.

Validity Note

The data and illustrations found in this book are not binding. We reserve the right to modify Schneider Automation's products in line with Schneider Automation's policy of continuous product development. The information in this document is subject to change without notice and should not be construed as a commitment by Schneider Electric.

Related Documents

Title of Documentation	Reference Number
ConneXium Ethernet Switch, 499NES25100 5-Port, 10/100 Base-TX Quick Reference Guide	31005153
ConneXium Ethernet Switch, 499NES18100 8-Port, 10/100 Base-TX Quick Reference Guide	31005416
ConneXium Ethernet Cabling System Switch Management Manual	31005844 (English) 31005845 (Français) 31005846 (Deutsch) 31005847 (Español)
ConneXium Ethernet Cabling System Quick Reference Guide (Electrical Switch 10/100 Mbps 7TX 499NES17100/Optical Switch 10/100 Mbps 5TX/2FX 499NOS17100)	31005848 (English) 31005849 (Français) 31005850 (Deutsch) 31005851 (Español)
499NTR10100 ConneXium Transceiver Quick Reference Guide	
Modicon Quantum Ethernet TCP/IP Module User Guide	840 USE 107
Modicon Quantum Ethernet Web Embedded Server User Guide	840 USE 115
Quantum 140 NOE 771 xx Ethernet Modules User Guide	840 USE 116
140NOE771xx/140NWM10000/140CPU651x0, Unity Pro 2.0 User Guide	
FactoryCast User's Guide For Quantum, Premium and Micro	31001229
FactoryCast HMI, Premium and Quantum HMI Modules, Setup Manual	35007415
Momentum 170ENT11001/170ENT11000 Ethernet Communication Adapter User Guide	870 USE 114
174 CEV 200 30 Modicon TSX Momentum Modbus Plus to Ethernet Bridge User Guide	890 USE 151
174 CEV 300 20 Mododbus to Ethernet Bridge User Guide	890 USE 195

Title of Documentation	Reference Number
Advantys STB Ethernet Modbus TCP/IP Network Interace Applications Guide	890 USE 177
TSX Micro TSX ETZ 410/510 Modules User Manual	3500473404
Premium and AtriumUsing Unity Pro Ethernet Network Modules User Manual	35006192
Ethernet Module Manuals for Unity	20110V20E
Altivar 58 Ethernet Modbus TCP/IP Communication Option Instruction Bulletin	VVDED300053
Sepam series 80 functions - Introduction	
EGX Installation Guide	63230-314-200B1
EGX User's Guide	63230-208A1
EGX Reference Guide	63230-314-202A2

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All pertinent state, regional and local safety regulations must be observed when installing and using this product. For reasons of safety and to assure compliance with documented system data, only the manufacturer should perform repairs to components.

User Comments

We welcome your comments about this document. You can reach us by e-mail at techpub@schneider-electric.com

Transparent Ready

1

At a Glance

Overview

This chapter introduces you to Transparent Ready, a major strategic program to deploy Internet technologies in Schneider Electric products and services.

What's in this Chapter?

This chapter contains the following topics:

Topic	Page
Transparent Ready	16
Transparent Ready Service Classes Offered	19
Users of this Guide	23
How this Guide Is Organized	24

Transparent Ready

What Is Transparent Ready?

In 1996, Schneider Electric proposed a combination of technologies that transformed industrial automation. This approach employed a combination of the physical and data link layers of Ethernet, as defined by the OSI model (see *p. 124*), with TCP/IP and Modbus for industrial Ethernet solutions. The concept, originally known as Transparent Factory, has evolved to become the Transparent Ready initiative.

Transparent Ready is a major strategic initiative that deploys Internet technologies into Schneider Electric's products and services. Any Schneider Electric product or service that supports Internet technologies is a Transparent Ready product.

What Are Internet Technologies?

Internet technologies describes a set of technological innovations that allow information to be managed through the Internet and related hardware, software, languages and protocols. They are used to transfer, present, and manage information. Examples include:

- Ethernet (wireless, fiber optic, copper, and other) media through which information is transferred
- Ethernet frame, the Internet protocol suite (TCP/IP), SOAP, and other protocols that transfer information
- Java, HTML, XML, and other language protocols that present the information

What Is Industrial Ethernet?

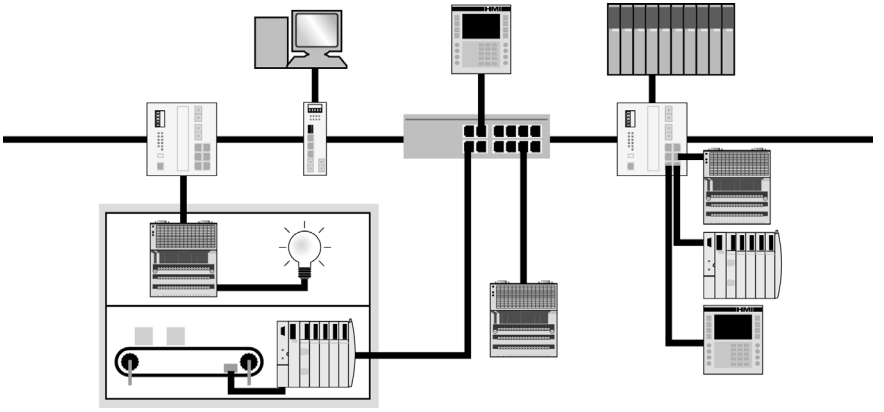
Ethernet refers to the way that data accesses the network, how the messages are framed for transmission and reception, and the physical characteristics of the network: topology, cables, connectors and infrastructure.

Industrial Ethernet is the commercial name adopted by the industrial automation market segment to refer to the use of Ethernet in an industrial environment. The term is now so generic that other Internet technologies are included even if Ethernet itself is not present. For example, Ethernet is not used in an industrial wireless 802.11 communication, but it is still considered an industrial Ethernet application.

A detailed analysis of industrial Ethernet (see *p. 27*) is presented in this manual, in which the different characteristics and origins of Ethernet, TCP/IP and Modbus are explained.

Industrial and Commercial Ethernet Comparison

In an industrial control environment, programmable logic controllers (PLCs) around the plant act as servers for the input and output (I/O) modules. PLCs may be interconnected by industrial fieldbuses, further distributing the data storage and management responsibilities. A PLC may act as a server for some devices and as a client for others:



The industrial network shown above is very different from a typical business and commercial applications. Due to the critical nature of many control applications, client devices throughout the industrial Ethernet system tend to be more intelligent than standard commercial Ethernet clients. The ways in which the client and server devices communicate with each other are defined by the Transparent Ready services that they use.

A business Ethernet network is designed with a bank of servers residing in a control room. Business data is stored and managed in this centralized area, and is sent to and from the clients through switches and routers dispersed throughout the enterprise. Firewalls secure the enterprise from unauthorized entry.

Industrial Ethernet is different from commercial Ethernet in three main areas: environmental, layout, and performance requirements.

	Office Ethernet	**Industrial Ethernet**
Environment	Suitable for human occupancy and work	Light-duty and heavy-duty industry
	Normal temperature range	Potential harsh environments
	Little dust, moisture, and vibration	Exposure to electromagnetic noise
	Hardly any mechanical loads or problems with chemicals	Extreme temperatures, climatic variables
	Low EMC requirements	Dust, moisture and vibration possible

	Office Ethernet	Industrial Ethernet
	Minimum pulling requirements	Risk of mechanical damage or problems with chemicals
		Required grounding and bonding of industrial equipment and cabling
Layout	Limited floor size in vertical buildings	Large manufacturing areas in only one floor
	Star topology	Star, bus, and daisy chain topologies may be used
	In accordance with office standards	Self-healing ring and redundant self-healing ring to maximize up-time
Performance	High network availability with reliable connections	High network availability (typically, 24X7 with redundancy)
	Large data packets	Low bandwidth usage always recommended (no higher than 40% at all times)
	Acceptable level of predictability	Small data packets. Predictability is essential

There are other areas of differentiation as well, such as the Ethernet services required.

The Transparent Ready Strategy

Transparent Ready offers a three-stage strategy:

1 *Expose industrial control information via open or de facto standards*
OPC and embedded Web server products open Schneider Automation devices to several systems that can access information and knowledge buried in the devices. Standard Web server technology allows any qualified personnel in the enterprise to interact with the automation system.

2 *Create interfaces and integration points between automation systems and business applications*
Using the device as a data server within a client/server architecture allows Schneider alliances to develop interfaces to business systems in Windows or UNIX environments.

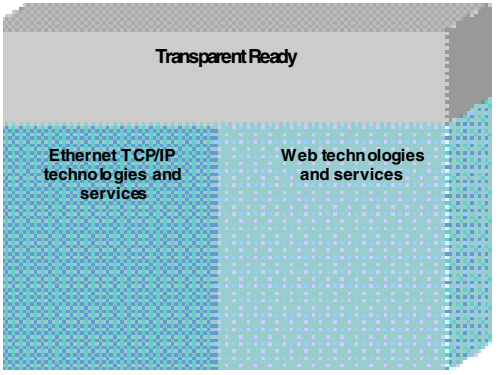
3 *Develop an open infrastructure that supports real-time and deterministic behavior*
The network is the backbone for an efficient information exchange. Ethernet, TCP/IP and Modbus are Schneider's primary choices for delivering an open network. Switches and hubs help to build real-time and highly available subnetworks and to address a broad range of applications.

Transparent Ready Service Classes Offered

Summary

The Transparent Ready service classes make it possible to identify the services provided by each product:

- Diagnostic, display and control services via Web technologies
- Ethernet communication services



Web Service Classes

Transparent Ready Web services are defined by 4 classes identified by letters:

- Class A: no Web services
- Class B: standard Web services
- Class C: configurable Web services
- Class D: active Web services

Transparent Ready products with an embedded Web server can provide 4 types of Web service:

- maintenance Web services
- control Web services
- diagnostic Web services
- optional Web services such as documentation or configuration

The following chart specifies the services provided by each Web service class:

Web Server Class		Web Services			
		Maintenance	**Monitoring and IT Link**	**Diagnostics**	**Optional**
D	Active Web Server	User Website update	Autonomous execution of specific services (e.g., alarm notification by E-mail, exchange with databases, calculations) SOAP/XML (client/server)	User-defined states	User documentation
C	Configurable Web Server		PLC variables editor Remote commands User Web pages SOAP/XML (server)	Communication service diagnostics State of internal product resources	
B	Standard Web Server	Remote device software update Remote auto-tests	Device description Data viewer	Device diagnostics	Configuration of network parameters and Ethernet communication services Device documentation
A	No Web Server	No Web services			

Ethernet Communication Service Classes

The Ethernet communication services provided by a product are defined in 3 classes. Each class is identified by a number:

- Class 10: standard Ethernet communication services
- Class 20: Ethernet communication management services (network level and product level)
- Class 30: advanced Ethernet communication services

Transparent Ready products can provide 8 types of Ethernet communication services:

- Modbus TCP messaging
- I/O scanning
- Faulty device replacement
- Network management (SNMP)
- Global data
- Bandwidth management
- Time synchronization (NTP)
- Email event notification (SMTP)

The following table specifies the services provided for each Ethernet communication service class:

Service Class	Ethernet Communication Services							
	Modbus Messaging	**I/O Scanning**	**FDR**	**SNMP**	**Global Data**	**SMTP**	**Bandwidth Management**	**NTP**
30	Direct read/ write of I/O	Periodic read/ write of I/O Configuration of the list of devices scanned	Automatic control/ update of device parameter configuration	Use of the MIB library by an SNMP manager	Publication and subscription of network variables	Event notification by email	Monitoring of local load level	Device clock synchronization
20			Automatic assignment of IP address and network parameters Control/ update of configuration and product parameters by the user	Product detection of by an SNMP manager				
10	Read/Write data words		Local assignment of IP address Verification of duplicate IP addresses					

Choice of Transparent Ready Products

The services provided by a Transparent Ready product are identified by a letter defining the level of Web service, followed by a number defining the level of Ethernet communication service. For example:

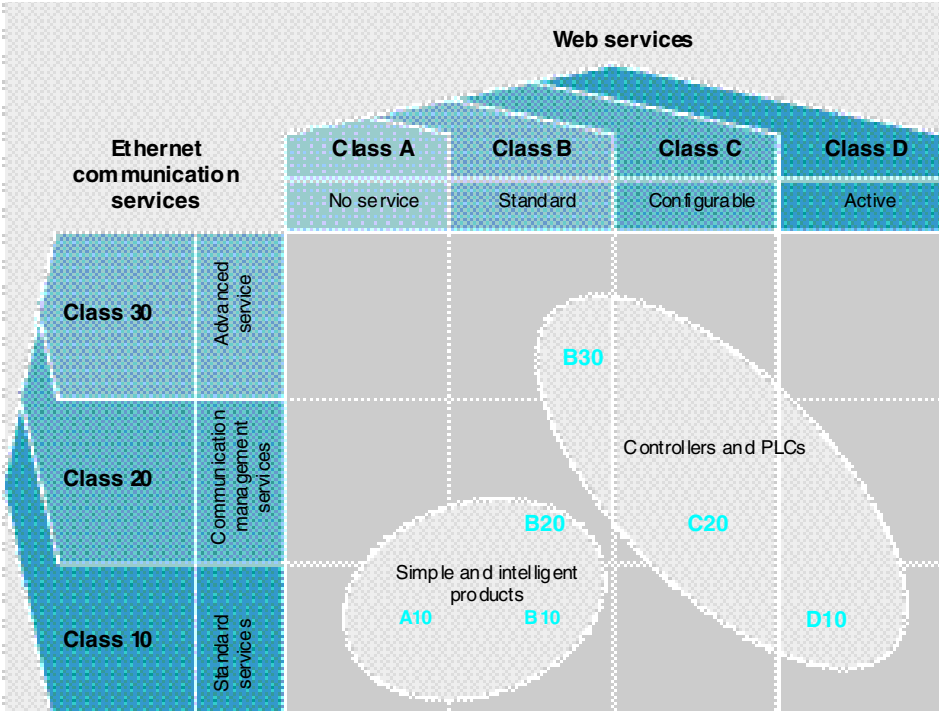
- A class A10 product is a product with no Web service and standard Ethernet services.
- A class C30 product is a product with a configurable Web server and advanced Ethernet communication services.

The services provided by a higher class include all the services supported by a lower class.

Transparent Ready products are chosen from 4 main families:

- sensor and preactuator type field products (simple or intelligent)
- controllers and PLCs
- human-machine interface (HMI) applications
- dedicated gateways and servers

The following selection chart can be used for choosing Transparent Ready products according to the required service classes.



Users of this Guide

Summary

To successfully design and troubleshoot an industrial Ethernet system, you need a mix of Ethernet IT and traditional automation knowledge. A collaborative relationship between the industrial control engineer and the plant IT professional is key to the success of a Transparent Ready system.

Audiences Analysis for this Guide

This table describes the two audience groups for whom this guide is written, their areas of expertise and their information needs. It also gives references to the sections of this guide where the needed information can be found:

Audience	Expertise	Knowledge Needs
IT Professionals	• TCP/IP protocol • Architectural alternatives, such as Ethernet switching • Network security issues • Hardware component selection • Open systems • Standards interpretation by different vendors • Network component selection	• Industrial plant environment and conditions • Network shielding from noise and interference • Physical network implementation in an industrial setting • Operational priorities: redundancy, quick recovery • Safety issues associated with the failure of automation controls
Industrial Control Professionals	• Control device interaction • Industrial installation requirements • Data transfer speed requirements • Recovery and redundancy needs	• Ethernet technology requirements • Transparent Ready service selection Transparent Ready services (see *p. 153*) • Open system environment requirements • Open system communications issues • Integration of products from multiple vendors • System design and protocols • System security issues

How this Guide Is Organized

Summary

A Transparent Ready system comprises two key elements:

- the Ethernet network over which the devices exchange application data
- the services that enable the transactions that happen on the network

The three chapters that follow contain stand-alone discussions of the major topics you will need to consider as you design a new Transparent Ready system or maintain an existing system. The chapters may be read in any order, based on the topics that interest you the most.

Physical Planning, Design and Installation

Physical Planning, Design and Installation of a Transparent Ready Industrial Ethernet Network, p. 27 describes how to design, install and verify your Transparent Ready industrial Ethernet network to best meet your application requirements, including the following considerations:

- design standards
- choice of cabling and components
- Internet technology overview
- environmental requirements
- protective earthing recommendations
- testing your network
- IP Addressing
- routing
- security

Transparent Ready Services

Services Overview, p. 153 describes each of the Transparent Ready services, the appropriate device choices for each, and the Transparent Ready devices that support each service. Service support is a very important device selection criterion. Choosing the right services enables you to account for the following system design issues:

- appropriate device response times
- avoidance of device overload
- application throughput requirements for the entire system

This chapter also explains how the different services operate and their expected performance.

Trouble-shooting

Troubleshooting, p. 341 provides procedures for how to maintain a Transparent Ready system after installation. These procedures include how to:

- identify problems such as
  - network infrastructure issues
  - device incompatibility
  - performance issues
  - environmental interference
- identify sources by:
  - device query and response times
  - device incompatibility
- identify resolutions such as:
  - device replacement
  - system redesign
  - work-arounds for an unfixable problem

Supporting Information

A set of appendixes containing the results of performance measurements is presented at the end of the guide. The results compare the response times and throughput rates of different Transparent Ready devices that use some of the key network services. There is also a detailed section on Standards.

Physical Planning, Design and Installation of a Transparent Ready Industrial Ethernet Network

2

At a Glance

Overview

This chapter discusses the topics concerning Ethernet that an automation or control engineer should consider when planning, installing, and verifying a Transparent Ready industrial Ethernet network.

In designing a Transparent Ready industrial Ethernet network to fit your facility, you should have a general knowledge of network layout, criteria for choosing components, issues pertinent to the design process and the existing standards for office network components and layout that guide industrial network development. You may consult your IT personnel or a variety of written and electronic sources for more detailed information.

The planning section provides a description of network topologies, an overview of applicable standards for offices and plants, overall design considerations, and recommendations for selecting components.

The installation section describes EMC installation and the installation of cables and connectors.

The section on verification discusses methods for your network.

What's in this Chapter?

This chapter contains the following sections:

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2.1 Required Standards

At a Glance

Overview

Office-based Ethernet standards are being enhanced and modified to meet industrial Ethernet requirements. These Ethernet standards are being combined with industrial standards to account for the environment in which an industrial Ethernet must operate and its performance and topology requirements.

Many standards are used to define industrial Ethernet. These standards are developed and maintained by different standards organizations and are related to the following:

- protocols
- the physical layer
- environmental requirements
- cabling structures
- cable specifications

Many of these standards are regional and may apply only to specific areas or countries.

What's in this Section?

This section contains the following topics:

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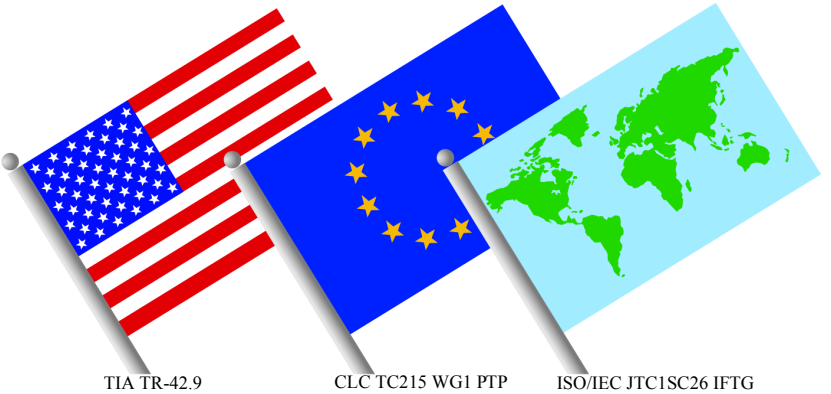
On-going Industrial Ethernet Standardization Efforts

Introduction

There are as yet no industrial Ethernet planning standards to refer to for guidelines and rules. There are, however, many recommendations for industry, based on the office environment standards (TIA/EIA-568-B, ISO/IEC-11801, and EN 50173), that have been placed before standards committees by several industrial networking organizations.

The most significant international standardization effort is by a collaborative group of experts from IEC TC65, TIA TR-42.9, and CENELEC TC215 WG1. Their work will be published as the ISO/IEC 24702 standard.



ISO/IEC 24702 Standard: Time Table and Definitions

Publication of the ISO/IEC 24702 standard is planned for sometime in 2006.

The ISO/IEC 24702 standard defines generic cabling for industrial premises and related IT specifications. For its definition of balanced cabling and optical fiber, it takes the following from ISO/IEC 11801:

- applications
- link and channel transmission classes
- transmission performance components

It also adds new concepts such as the classification environment (as presented below in the MICE table), suitable components, and a modified cabling structure.

MICE Concept Mechanical Rating

The IEC TC65C working group originated the MICE concept of mechanical rating to define environmental parameters and their requirements. MICE includes three environmental classes:

- Class 1: for general (non-industrial/non-residential)
- Class 2: for light industrial
- Class 3: for heavy industrial

It also defines the environmental parameters on which its name is based:

- **m**echanical
- **i**ngress
- **c**limatic
- **e**lectromagnetic

Each environmental parameter has a low-level (1), medium-level (2), and high-level (3) rating that is indicated in subscript beside each parameter's letter, for example $M_2I_2C_3E$. As you can see from this example, parameter levels may be mixed and may vary along a single channel.

Each environmental class has a worst case scenario as given below:

- $M_1I_1C_1E_1$: for a general (ISO/IEC 11801) environment
- $M_2I_2C_2E_2$: for a light industrial environment
- $M_3I_3C_3E_3$: for a heavy industrial environment

The MICE table is shown below:

		---> Increasing Severity --->		
		Class		
Mechanical	Shock/Bump	M_1	M_2	M_3
	Vibration			
	Tensile Force			
	Crush			
	Impact			
Ingress	Particulate	I_1	I_2	I_3
	Immersion			
Climatic	Temperature	C_1	C_2	C_3
	Ambient			
	Rate of Change			
	Humidity			
	UV Radiation			
	Solar Radiation			
	Liquid Pollution			
	Gaseous Pollution			

		---> Increasing Severity --->		
		Class		
Electromagnetic	ESD	E_1	E_2	E_3
	Radiated RF			
	Conducted RF			
	EFT			
	Surge			
	Magnetic Field			

ISO/IEC 24702: Unification of Major Standards Committees

To avoid different proprietary developments, the Customer Premises Cabling working group (ISO/IEC JTC 1 SC 25 WG3) was created. This group in turn launched the Industrial Premises Task Group (ISO/IEC JTC 1 SC 25 WG3.IPTG). To achieve maximum cooperation and expedite the development of an international standard, the Industrial Premises group has directly involved experts from the major standards organization committees (IEC TC65C, TIA TR42.9, and CENELEC TC215 WG1). The purpose of this new group is to standardize the characteristics of cabling systems for industrial facilities. The standard will be published as ISO/IEC 24702.

The Industrial Premises Task Group is jointly led by ISO/IEC JTC 1/SC 25 and IEC SC 65C.

- The JTC 1/SC 25 subcommittee is responsible for cabling for building sites.
- The IEC SC 65C subcommittee is responsible for cabling for process control. The IEC SC 65C is a subcommittee of the IEC TC65C in charge of developing standards for industrial networks.

Due to the fact that the ISO/IEC 24702 standard is currently being developed, Schneider Electric suggests that you follow the guidelines that are defined in this chapter.

Required Standards for Planning and Installation

Ethernet Standards

The Ethernet standard to consider when you plan an industrial Ethernet network is the one defined by the IEEE and adopted by ISO/IEC:

IEEE standard 802.3, 2002 Edition, Part 3: Carrier sense multiple access with collision detection (CSMA/CD) access method and physical layer specifications.	IEEE 802.3
Information Technology. Telecommunication and Information exchange between systems. Part 3: Carrier sense multiple access with collision detection (CSMA/CD	ISO/IEC 8802-3

IT Structured Cabling Standards

Cable manufacturers, suppliers, building designers, network architects, and service technicians all rely on cable standards to provide the specifications for their projects. These specifications include all aspects of the planning, design, and installation phases, as well as the configuration, performance, conformance testing, and verification of the final system.

The three major world standards shown in the table below are the foundations for cabling planning, selection, installation, and performance of IT networks. Each standard in the table is based on the one that precedes it. As a result, all of the standards are very similar.

Area and Standard		**Standards Organizations**	**Description**
United States	TIA/EIA-568-B	Telecommunications Industry Association Electronic Industries Association	Commercial Building Telecommunication Cabling standard - defines how to design, build, and manage a structured wiring system.
International	ISO/IEC 11801	International Organization for Standardization International Engineering Consortium	Generic Customer Premises Cabling standard - defines general cabling specifications for customer premises; based on TIA/EIA-568.
Europe	CENELEC EN 50173	Comité Européen de Normalisation Electrotechnique	Defines generic cabling and European open-market cabling components; based on ISO 11801.

Environmental Standards

Environmental standards are not specifically related to industrial Ethernet, but apply to any device or equipment located in the particular environment.

Schneider Electric has defined three types of environments that coincide with the MICE table:

- office environment, where standard Ethernet can be used
- light industrial environment
- heavy industrial environment

The environmental requirements for industrial Ethernet are defined by the same specifications that cover other industrial automation devices (see *p. 67*).

2.2 Physical Planning and Layout

At A Glance

Overview

This section presents cabling standards for an industrial Ethernet network. It also describes layouts for a Transparent Ready industrial network. To assist in understanding this structure, basic network topologies are reviewed. LAN technologies and issues relevant to an industrial Ethernet network are discussed, as are WAN technologies and hardware.

What's in this Section?

This section contains the following topics:

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Industrial Ethernet Cable Planning

Introduction

Because there are as yet no defined standards for the physical layout of an industrial Ethernet network, Schneider Electric has chosen to conform to the recommendations submitted by standards organizations such as Modbus-IDA, IAONA, PNO, and the work in progress by the IEC.

An industrial manufacturing site is a physical facility in which manufacturing or process control activities take place. In most cases, the site consists of multiple buildings or plants that manage interconnected, but separate, processes. The physical layout and environmental variables inherent in each of these facilities may result in different requirements for the cabling system at each site. This section describes Schneider Electric's recommendations for planning industrial Ethernet networks for manufacturing and process control environments.

Cable Planning

A network site plan communicates the physical and logical layout of a network that is specific to your site requirements. This plan is an important part of the network design process for your facility. The site may be an industrial facility or an infrastructure site. Infrastructure sites include environments, such as tunnels, water treatment plants and airports, with additional requirements to those of an industrial site. Both types of site have environmental variables that may be extreme compared to office environments. The existing standards for office environments, though useful and valid, have limited application in such environments. Application performance under rigorous environmental requirements, including climatic conditions and ingress protection, has a higher priority in an industrial environment.

The following topics provide general information on planning an industrial Ethernet network for industrial and infrastructure applications. This information does not attempt to cover every possible variation of these two environments. You should adapt this information to the specific needs of your site.

Structured Cabling Standards

Introduction

Schneider Electric recommends the use of structured cabling standards including TIAEIA 568B, ISO/IEC 11801 and CENELEC EN 50173 (see *p. 32*). Standards for cabling are currently being developed by a working group of the standards organizations.

Elements of a Cabling System

The table below shows the elements of a cabling system as defined by the ISO/IEC 11801 standard. This standard also identifies the interfaces through which different network components are connected to the cabling system.

Elements (Hierarchical Order)	Abbreviation	Purpose
Campus Distributor	CD	distributor from which the campus backbone cable emanates
Campus Backbone Cable		cabling between buildings that share telecommunications facilities
Building Distributor	BD	the distributor where the bldg. backbone cable terminates, connections to campus backbone cable are made
Building Backbone Cable		intermediate cable & connecting hardware
Floor Distributor	FD	connects the horizontal cable system to other cabling subsystems
Horizontal Cable		cabling between and including the telecommunications outlet and the horizontal distributor
Transition Point (optional)	TP	location in horizontal cabling subsystem where flat undercarpet cabling connects to round cabling
Telecommunications Outlet	TO	female telecommunications device found in the work area

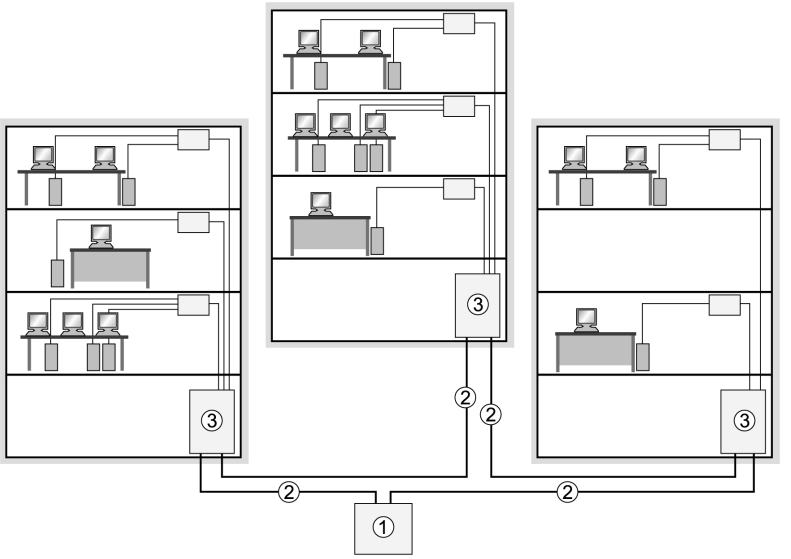
Cabling Subsystems

For a cabling installation to conform to the ISO/IEC-11801 standard, the configuration must connect the following subsystems of a cabling system:

- campus backbone; campus uses building distributors
- building backbone; every building has a building distributor
- horizontal cabling; every floor has a floor distributor

Structure of Cabling Systems

The generic cabling system defined by the ISO/IEC 11801 standard is a hierarchical star structure (see *p. 44*). The diagram below shows a central campus distributor and a campus backbone cabling system linking multiple building distributors. Each building is required to have at least one building distributor. Each building distributor connects to the central campus distributor using a star topology. The campus distributor becomes the central communication unit. As a backup and safety precaution, you should create redundant links between buildings. Within a building, every floor has its own floor distributor that serves up to 2000 m2 of office space.



1 Central campus distributor
2 Campus backbone cabling
3 Building distributor

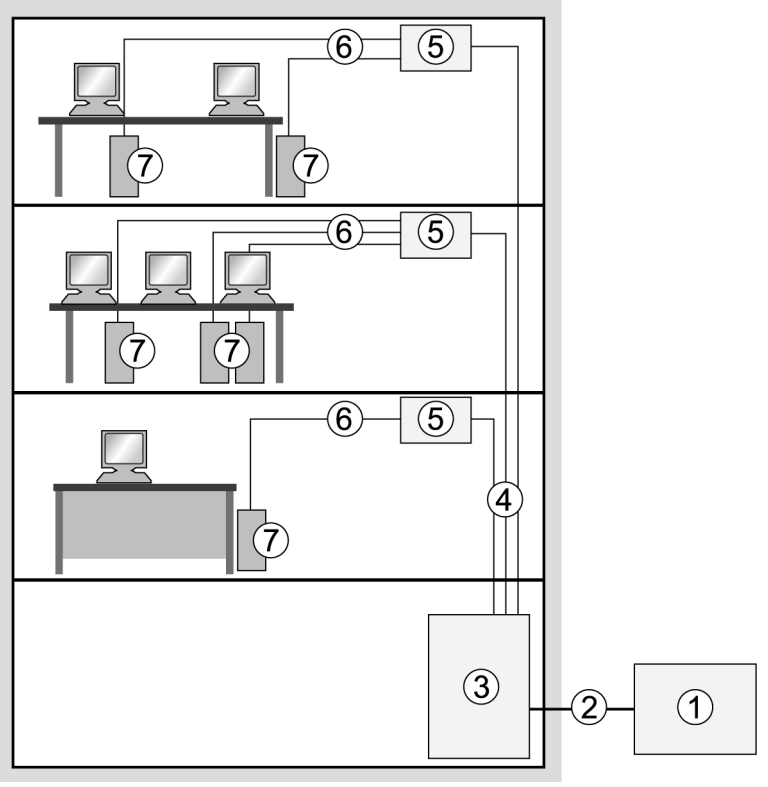
In a campus that has only one building, the primary distribution point becomes the building distributor in that building. However, it is possible for a large building to act as a campus and have one campus backbone with several building distributors.

The number of subsystems and type of elements included in your implementation depend on the following:

- size of the campus or building
- geography of the site
- purpose of the cabling system (applications and equipment)
- types of end user

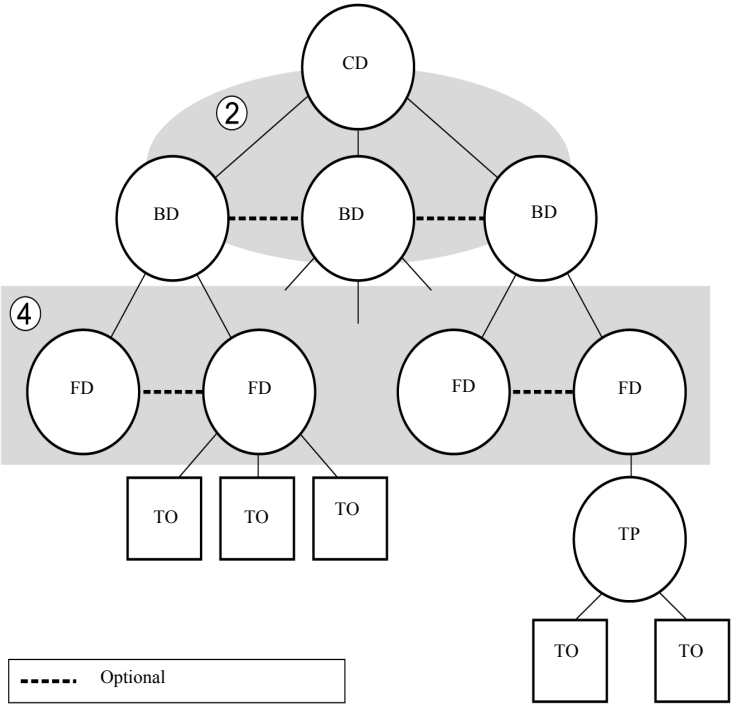
Configuration

It is possible to configure a generic cabling system to your specific needs by rearranging the distributors to support different topologies (see *p. 43*), such as bus, star, and ring. The following diagram shows the linear connections of a cabling system from campus distributor to the terminal outlet and equipment.

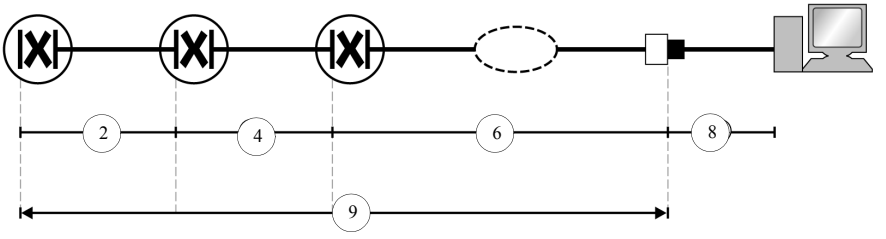


1 Campus distributor
2 Backbone cabling
3 Building distributor
4 Secondary cabling
5 Floor distributor
6 Tertiary cabling
7 Telecommunication outlet

The next two diagrams show how a generic cabling system can be physically implemented in a single building or multiple buildings along a campus backbone.



2 Backbone cabling
4 Secondary cabling



2 Backbone cabling
4 Secondary cabling
6 Tertiary cabling
8 Patch cord
9 Generic cabling system

Cabling in a Transparent Ready Industrial Ethernet System

Introduction

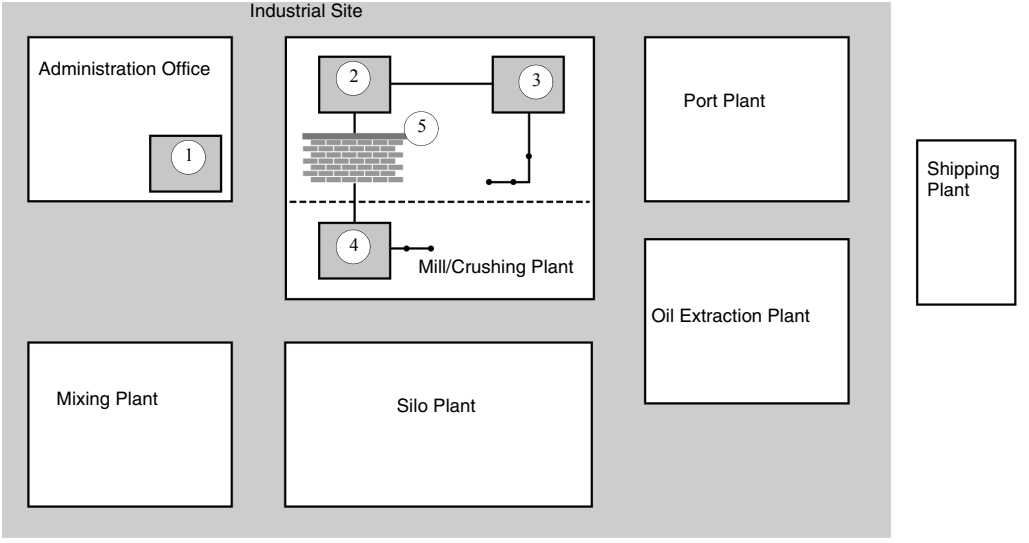
The Transparent Ready approach to planning a cabling system is similar to that of industrial Ethernet organizations such as Modbus-IDA, based on the accepted ISO/IEC 11801, EN 501731, and TIA/EIA 568B standards.

Multiple Plant Site Example

The following diagram shows a cabling system with the following parameters:

- an industrial site distributor that acts as the central communication unit instead of a campus distributor (see *p. 36*) and connects plant distributors along an industrial site backbone
- plant distributors that connect office plant and plant floor distributors along a plant backbone
- plant floor distributors that connect to cabinet distributors (CD, also called machine or field distributors, FD) and the devices and device outlets (DO) inside the cabinet
- office plant distributors that connect to telecommunications outlets that are themselves connected to printers and computers

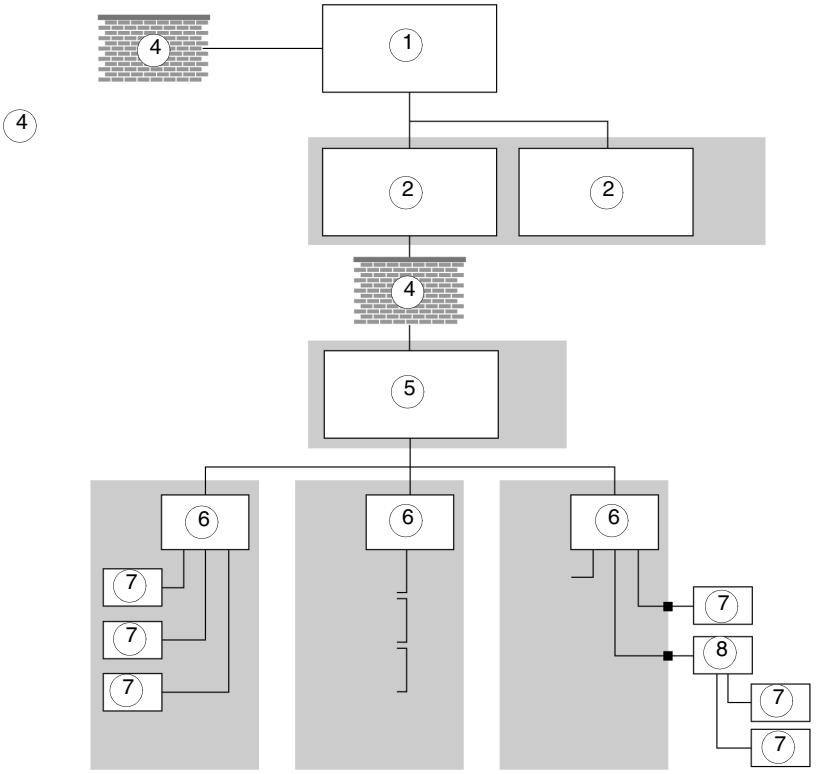
It is important to understand that a site may have many plants within it. The following example shows an overview of a grain site with 6 plants.



1 SD Site distributor
2 PD Plant distributor
3 POD Plant office distributor
4 PFD Plant floor distributor
5 FW Firewall

SIngle Plant Example

The following illustration is a closer view of a single grain plant within the site shown in the previous figure.



1 SD Site distributor
2 PD Plant distributor
3 POD Plant office distributor
4 FW Firewall
5 PFD Plant floor distributor
6 CD Cabinet distributor
7 DO Device outlet
8 FD Field distributor

Industrial Site Distributor

An industrial site distributor plays the same role as a campus distributor in the ISO/IEC 11801 standard, as the distributor from which the backbone cable emanates. This distributor is managed by IT personnel and can be one or more devices (racked switches) with multiple numbers of ports. Typically, it is located in an office environment and provides the connection for the entire manufacturing site to the Internet and to other physical sites in the same company or organization. Traffic in and out of the site is isolated by a router (see *p. 65*) and secured by a firewall.

Industrial Site Backbone

The industrial site backbone is the cabling system that extends from the industrial site distributor to the plant distributors. Typically, the industrial site is a self-healing ring (see *p. 51*) that can be made redundant with a dual self-healing ring (see *p. 53*).

Plant Distributor

The plant distributor connects the industrial site backbone to a plant. It acts as a building distributor. Most industrial sites consist of one or more separate plants. These different plants may have control rooms from which the plant is operated, or motor control centers where the MCC and control devices are located. Typically, the plant distributor is located in either the control or MCC room. The environmental requirement for a plant distributor is either office or light-industrial.

Office Plant Distributor and Plant Floor Distributor

As mentioned previously, the plant distributor is usually located either in the control or MCC room; the plant distributor is connected to the other distributors, such as the office plant distributor and the plant floor distributor. The office plant distributor manages the terminal outlets for the plant office. These terminals are used to connect printers, computers, and video conferencing devices. The plant floor distributor manages equipment on the plant floor. In most cases, these two distributors are located in either an office or a light-industrial environment. The office plant distributor is usually managed and maintained by IT personnel. The plant floor distributor is managed by personnel responsible for the cabinet distributors (also called field distributors or machine distributors). The traffic between the plant floor distributor and the plant distributor is isolated with a router and secured with a firewall.

Cabinet, Field, and Machine Distributors

Typically, cabinets contain devices with a low number of ports or connections, such as switches. Cabinet distributors (also called field distributors or machine distributors) provide connectivity to the devices located inside a cabinet, in a machine, or on the plant floor.

The following table shows the environmental requirements based on the location of the devices.

Device Location	Environmental Requirement
Inside a cabinet	Light industrial environment
In a machine	Light or heavy industrial environment
On plant floor	Heavy industrial environment

Inside the cabinets, the configuration is star or daisy chain (using devices with two Ethernet ports). The next topic (see *p. 43*) presents some typical network topologies and how they can be developed in an Ethernet environment.
These topologies are usually deployed beginning with the plant floor distributor. Device outlets (DOs) are located inside the cabinet. If the devices are located on the plant floor, there can be either a DO or a new distributor for devices in the field (called a field distributor or FD).

Understanding Basic Network Structure

Summary

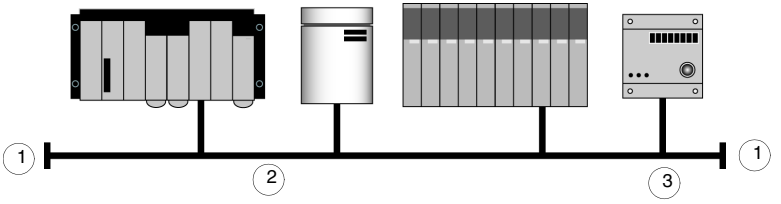
The physical layout, or topology, of a network consisting of cables, components and devices can be structured in any of several architectures:

- bus
- star
- daisy chain
- ring
- dual ring
- mesh

Illustrations of each type of layout are included. Each layout has its advantages and disadvantages, as shown in the tables. Switches and hubs are mentioned in conjunction with the network architecture. Schneider Electric recommendations for network layout are also discussed.

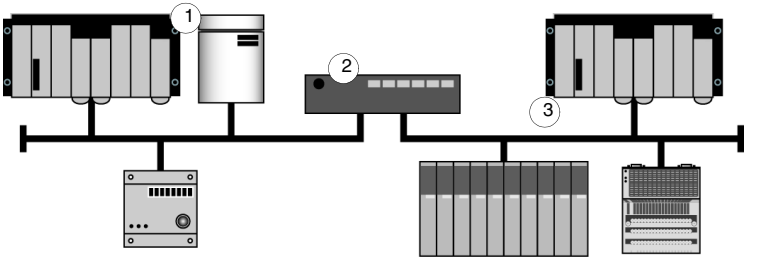
Bus Topology

A bus topology has a similar layout to a more traditional automation network such as the Modbus Plus. A single backbone cable connects all the devices on the network. Terminators are placed at each end of the backbone to allow signals to be sent and cleared over the network. Devices, usually connected using T-connectors, can be installed anywhere along the bus.



1 terminator
2 backbone
3 T-connector

A section of backbone cable is known as a *segment*. Several segments can be connected using bridges or repeaters, as shown in the illustration below.



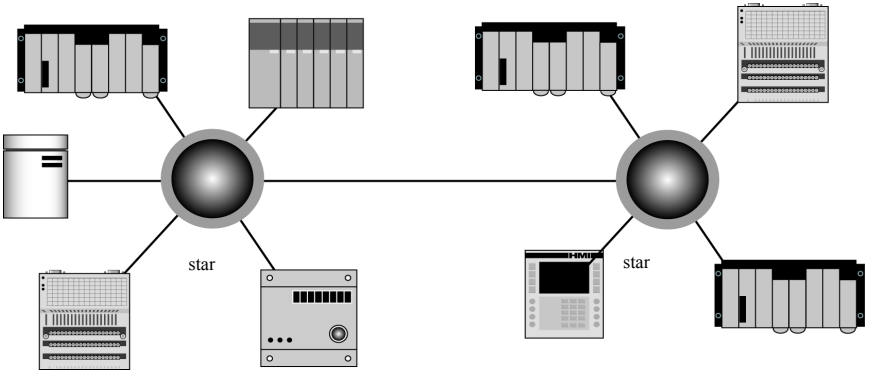
1 Segment 1
2 Repeater
3 Segment 2

Only one device at a time can send or transmit a packet of information. The packet travels the entire bus backbone cable. For this reason, a bus topology is considered a shared medium. Terminators are very important because a cable break can result in all devices losing their ability to communicate.

Advantages	Disadvantages
Low cost.	Scalability is a problem; it is difficult to change the network as your needs change. As traffic and the number of devices increase, the performance of the network decreases.
Easy installation; all network devices are connected to a cable segment, and you need only enough cable to connect the equipment that you have.	The devices are usually connected using taps into the trunk cable. If a device or segment is lost, all the devices further down the line could become unavailable.
The backbone follows the a path around the plant much like a proprietary automation network, making the network design easy to understand for designers new to Ethernet-in-automation applications.	Because all the devices share the same backbone cable, the throughput is limited; only one device can communicate at any time.
	The speed of all devices on a bus network must be the same.

Star Topology

In a star topology, all the devices are connected though a central device. A star topology is a common network layout for office environments and also for newer automation environments.



In a star topology, devices can use dedicated sections of the network for various services.

Advantages	Disadvantages
Network throughput is much higher than on a shared-media bus topology.	Star topologies are more costly because a dedicated cable must be run to each device. To offset this disadvantage, network infrastructure components (switches, hubs, etc.) are used in cabinets on the factory floor so that a group of local devices can be connected together. A single long cable can be run back to a central point to support the group, rather than using separate cables for each device.
Network reconfiguration is much easier.	
Centralizing network components makes administration easier; centralized management and monitoring of network traffic enhances network performance.	
Diagnostics are simple; if a network segment fails, it affects only the devices directly connected to that segment.	
Infrastructure components use monitoring software and device-based LEDs to indicate failures; most single points of failures can be diagnosed and repaired quickly.	
Resilience; a cable failure takes only that device out of service.	
You can have more devices on a single network than on a bus topology.	

Daisy Chain Topology

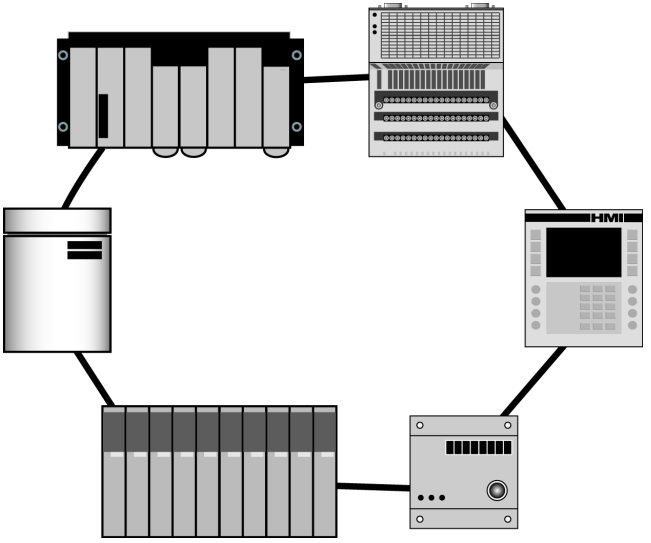
In daisy chain topology, the device is part of the trunk cable, unlike in bus topology where the device is connected to the cable through a tap connector and is not considered part of the trunk cable. Every device in a daisy chain has two network ports; information flows through the device. Although a daisy chain is linear, there are branching devices available that allow the development of more complex topologies.

The Interbus is an example of as daisy chain network.

Advantages	Disadvantages
Low cost; there is no need to consider Tap connectors.	In a linear configuration, if a device fails, the network gets cut.
	If not properly designed, the devices in a daisy chain may become overloaded trying to manage the information flowing through them.
	Potential network overload; all devices share the same trunk cable.

Ring Topology

In a ring topology, all devices or network infrastructure components are connected in a loop with no beginning or end. Packets travel in a single direction on the ring as they are passed from one device to the next. Each device checks a packet for its destination and passes it on to the next device.

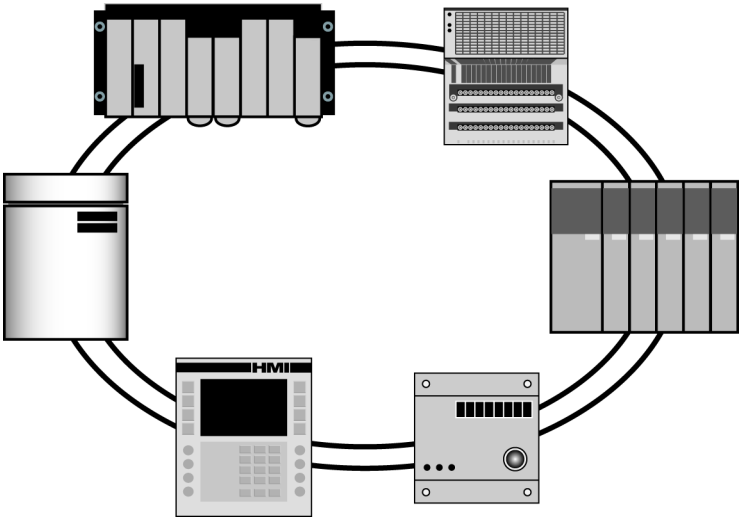


Ring topologies provide redundancy. The failure of a single link is handled by routing traffic in the opposite direction. A ring may be based on token rotation or random/shared access. Alternatively, it may be a switched network where all the devices access the network at the same time at different speeds.

Advantages	Disadvantages
Redundancy; the failure of a single link or infrastructure component does not affect the entire network.	High cost; more cabling is needed to complete the ring.
A ring topology uses software to monitor the network links.	Network infrastructure components need intelligence to respond to device failures; they are more costly than simple bus or star components.

Dual Ring Topology

When industrial automation systems are used in critical applications where downtime is unacceptable, a dual ring topology may be deployed.



A dual ring has all the features of a single ring with more fault tolerance. It comprises infrastructure components connected together with multiple rings. Each device is connected to two infrastructure components. Each infrastructure component is connected to a separate ring. When a single link or infrastructure device fails, all other devices can still communicate.

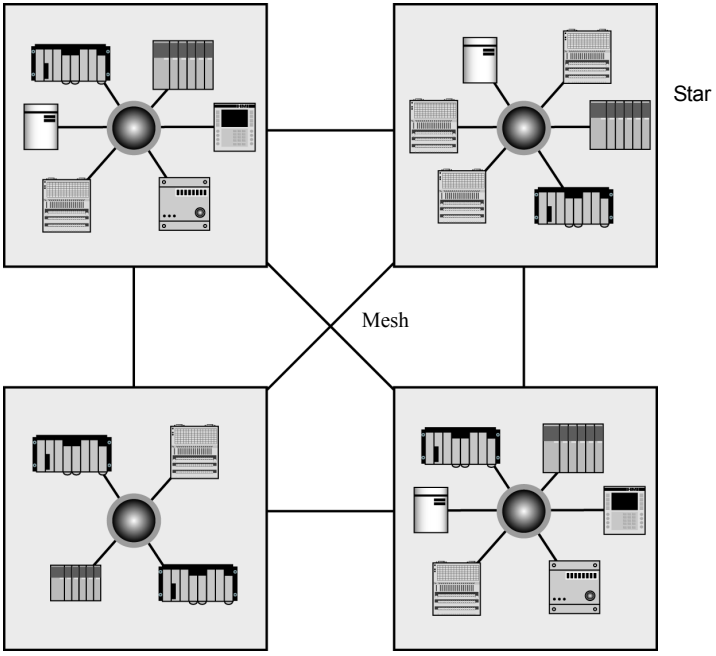
Dual ring topologies used in automation environments have additional features not always found in typical data communications environments. For example, hot standby links are used between rings. When a link fails, the standby becomes active and prevents any interruption in network communications. Watchdog packets are sent out to inactive connections and they create logs if the connection remains inactive. The watchdog packets create log entries that are monitored by the network administrator.

Advantages	Disadvantages
Redundancy; the failure of multiple devices or cables does not cause the network to fail.	Cost, compared to a single ring, since the amount of equipment is doubled.
Separate power supplies can be used for each ring.	The need to regularly monitor unused links so that they are known to be healthy in the event that they are needed.
Multiple interfaces within a device can connect the device to different rings so that the flooding of one ring with collisions or broadcast traffic does not cause the system to fail.	

Mesh Topology

A mesh topology is used in very large networks or network backbones where every end device or infrastructure device has a connection to one or more components of the network. Ideally, each device is directly connected to every other device in the mesh.

Another mesh implementation is as a network backbone that connects separate star structures. This combined topology provides fault tolerance to the backbone without the high cost of a mesh topology throughout the entire network.



Mesh topologies are used less frequently because of cost and complexity.

Advantages	Disadvantages
Fault tolerance; if a break occurs anywhere in the network cable segment, traffic can be rerouted.	Complexity; difficult to manage and administer.
	High cost; more cabling and interfaces are needed to support the redundant connections.

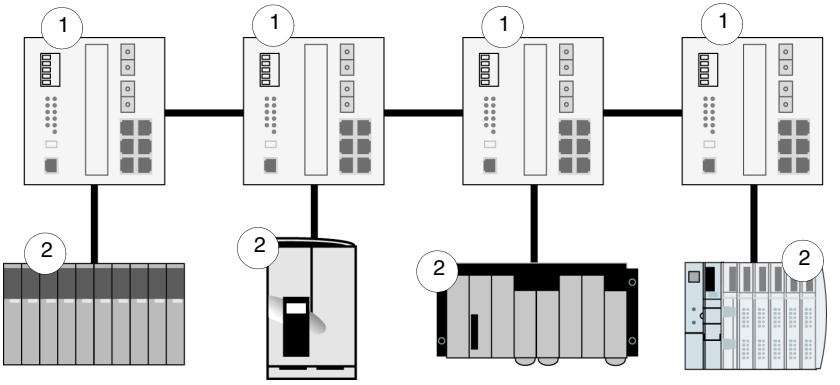
Developing Network Architecture for Industrial Ethernet Networks

Introduction

Along with a basic understanding of network architecture (topologies) and Ethernet for office environments, there are some further considerations when deploying Ethernet in a plant environment. The various topologies and their application in an automation plant layout are discussed, with suggestions for appropriate hardware.

Ethernet Bus Topology

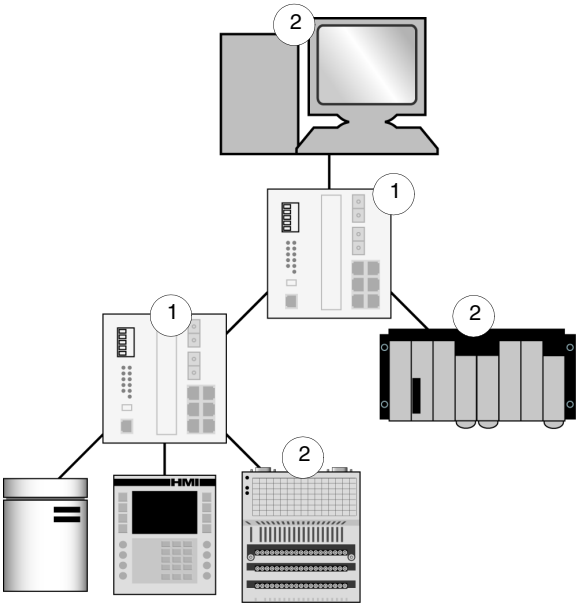
An Ethernet bus can be deployed by interconnecting hubs and/or switches in line and considering each one of them as the connection for a device. A limited number of hubs and an unlimited number of switches can be interconnected to achieve this purpose.



1 Ethernet switches
2 Ethernet devices

Ethernet Star Topology

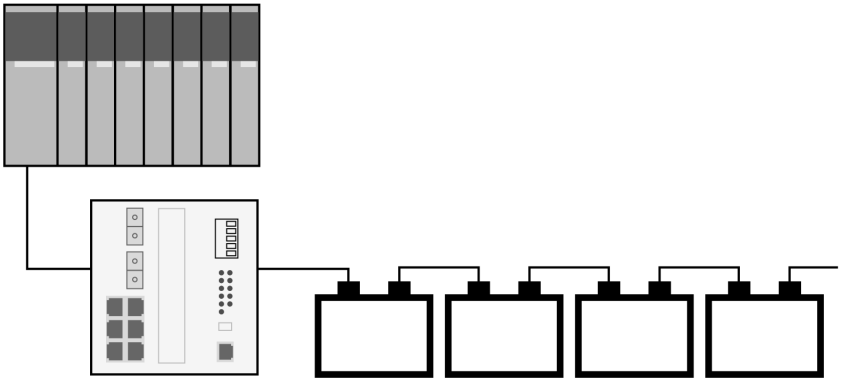
In an Ethernet star, the intermediate device may be a hub or a switch. A star is the most commonly used topology in office networks and has been adopted in most automation applications. For industrial Ethernet applications, the use of a full duplex switch as the central device, rather than a hub, is strongly recommended.



1 Ethernet switches
2 Ethernet devices

Ethernet Daisy Chain Topology

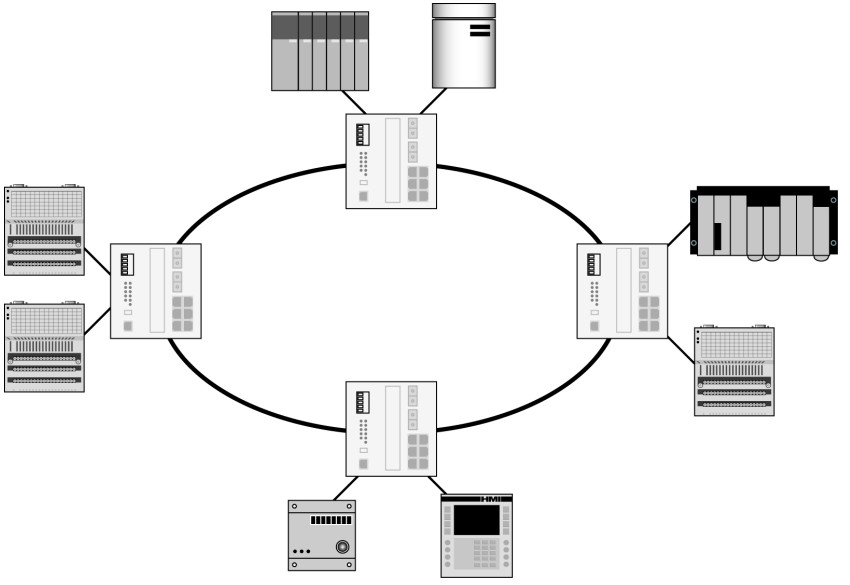
To develop an Ethernet daisy chain network, devices with dual Ethernet ports are required. Schneider Electric is releasing industrial Ethernet devices with this type of functionality (dual Ethernet ports for daisy chain connectivity) at the present time.



Ethernet Ring Topology

Ethernet rings usually form the backbone for high-availability applications. Two paths are available to reach the same device. If ring topology is required, switches that support either a proprietary ring topology or spanning tree protocol (either spanning tree or rapid spanning tree) need to be used.

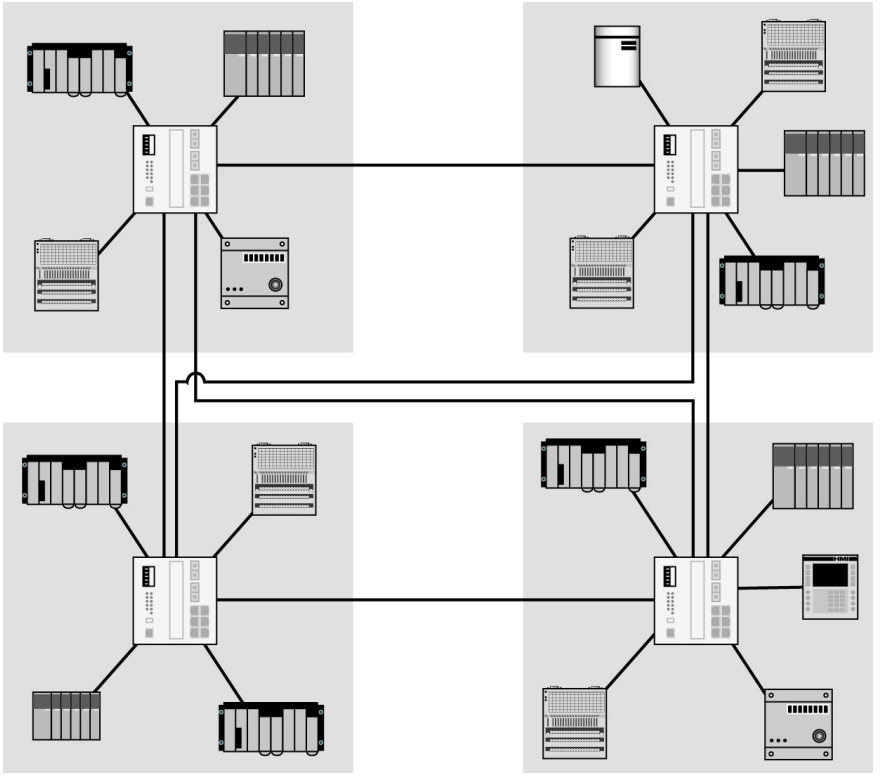
Spanning tree protocol (STP; IEEE 802.1D) or rapid spanning tree protocol (RSTP; IEEE 802.1w) are protocols that avoid communication loops and find a new communication path when the initial one is no longer available. The recovery time (time to find a new path) is about 30 s with STP. With RSTP and proper network design, recovery time could be as low as 100 ms.



Ethernet Mesh Topology

An Ethernet mesh network offers more redundancy than an Ethernet ring architecture. In a ring, two paths are typically available to the same device. In a mesh network, more than two paths are typically available.

To develop an Ethernet mesh topology, switches that support spanning tree or rapid spanning tree protocol are required.



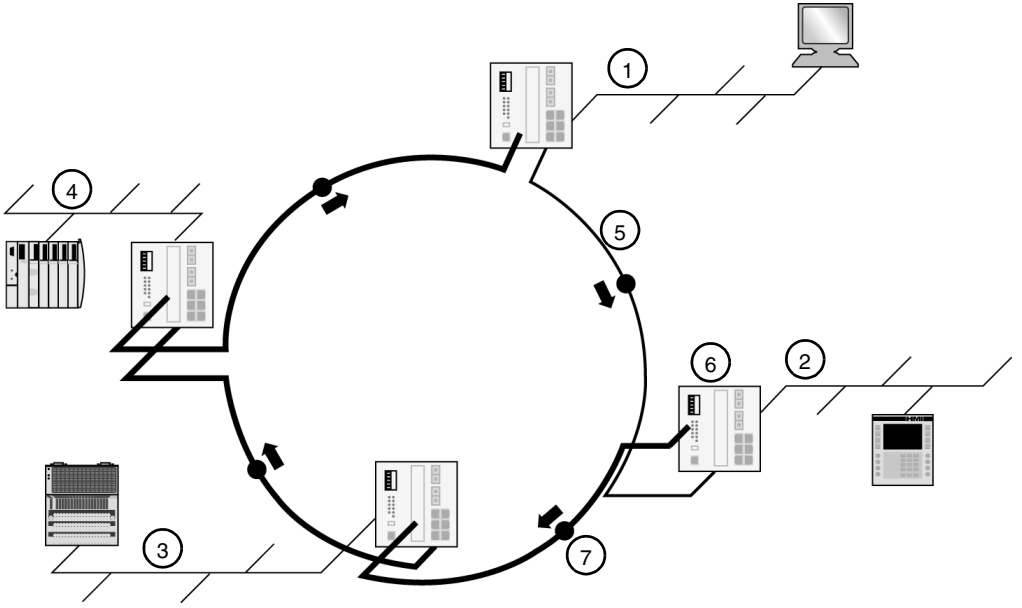
Redundant Ring Topology

Summary

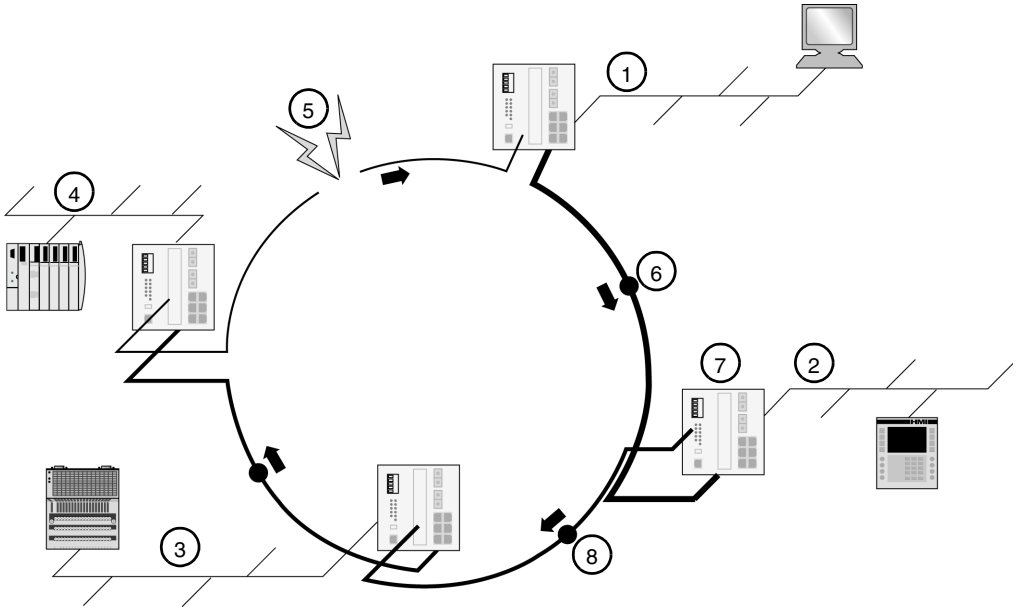
A redundant ring topology is recommended for automation environments where there is a critical need for a fault tolerant network. Unlike a dual ring topology where there are two links on every device, a redundant ring uses logical management on the switch to reroute traffic across a single link structure.

Self Healing Operation

When a link on the redundant ring fails, a standby link is activated within a fraction of second. Through the use of a redundancy manager, the switch monitors the ring using watch-dog packets. If one link in the ring fails, the redundant connection performs self healing by activating the redundant link to take over data packet transmission. Once the broken link is resolved, the self healing link is re-activated.



1 Process control
2 Production line 1
3 Production line 2
4 Production line 3
5 Redundancy connection
6 Redundancy manager active on switch
7 Watch dog packets



1 Process control
2 Production line 1
3 Production line 2
4 Production line 3
5 Network fault
6 Redundancy connection takes over data packet transmission
7 Redundancy manager active on switch
8 Data packet able to reach all nodes

Advantages	**Disadvantages**
Less complex, requiring only a single physical connection.	If two links fail simultaneously, connectivity could be lost to critical devices.
More cost effective; a single interface and network are used.	
Automatic self healing that detects faults and reroutes data packets.	

LAN Technologies and Network Design

Summary

Avoiding disruptions in data transfer is an issue of paramount importance to an industrial network planner, perhaps even more of a priority than throughput (speed of information transfer). Discussed below are issues of network design such as congestion, collision management, and broadcasting that can influence the smooth, fast transfer of information along the network. Suggestions are given for proper network design that can minimize the potential for disruptions.

Whereas several technologies can be used to build an IP network, Ethernet has emerged as the preferred technology for both office and industrial environments.

Ethernet Advantages and Standards

Among the LAN technologies, Ethernet has become the most popular because it offers the benefits of speed, cost, and ease of installation. It can support virtually all popular network protocols and has gained wide acceptance in the computer marketplace as an excellent networking technology for most network environments.

The IEEE defines rules for configuring an Ethernet network and specifying how elements in an Ethernet network interact with one another in IEEE Standard 802.3. Adherence to IEEE 802.3 enables your network equipment and network protocols to communicate efficiently. Refer to the information on the OSI (see *p. 124*) model.

Fast Ethernet and Gigabit Ethernet

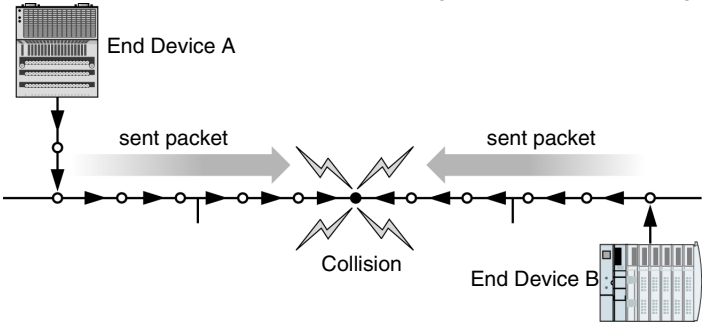
Ethernet networks that require higher transmission speeds may use the fast Ethernet standard (IEEE 802.3u), which raises the Ethernet speed limit from 10 to 100 Mbps with only minimal changes to the cabling. The fast Ethernet 100Base-TX has become the most popular standard because it is very compatible with the existing Ethernet 10Base-T. Gigabit Ethernet (1000 Mbps) is a technology under development (IEEE 802.3z) that may allow the next generation of networks to support even higher data transfer speeds.

Ethernet Frames/ Packets

The network sends data in units called *frames* (also called data frames or packets). Each frame can carry between 46 and 1500 bytes of data. A frame includes protocol information for proper routing.

Ethernet and Collisions

Because Ethernet allows multiple devices to exchange data simultaneously, collisions can occur when two devices transmit data at the same time. When this happens, both devices stop transmitting and use a random back-off algorithm to wait a certain amount of time before attempting to transmit the data again.



Collisions can be managed by careful network planning and design. The following design and operation factors may affect the collision rate of an Ethernet network:

- the number of devices on the network; the more devices, the more likely collisions become
- the length of the network; the greater the chance for collisions
- the packet length or MTU size; a larger packet length takes longer to transmit, thus increasing the chance for a collision. The larger the frame size, the more chance for a collision.

Switched Networks and Collision Domains

Switches, when properly designed into the network structure, are the key to avoiding network slowdowns due to collision or congestion. Intelligent switches create less network traffic by sending data only to the destination that requires it. They can also filter out bad packets, preventing them from being forwarded further. Switches also divide a network into separate, shorter domains that each carry less traffic. Full-duplex switches (see *p. 59*), which allow transmission of data in both directions, can increase bandwidth and completely eliminate collisions on the segments where they are used. Schneider Electric recommends the use of full-duplex switching in automation networks.

Network Congestion

Performance on a shared network deteriorates when more devices or applications that require more data are added. Increased collisions can be the result of too many end devices or too much traffic on the network. For example, actual throughput on a moderately loaded 10 Mb/s Ethernet network is approximately 35% of capacity, which is about 2.5 Mb/s (after figuring for packet overhead, interpacket gaps, and collisions). A moderately loaded fast Ethernet shares 25 Mb/s of real data in the same situation. Collisions increase on both networks as more nodes and/or more traffic are added to the shared collision domain. Again, good planning, in segmenting the network and by using intelligent switches, aids in reducing congestion and maintaining good performance.

Ethernet Broadcast Domains

A broadcast is the transmission of the same message to multiple recipients on the network. Any device configured for network broadcast receives that message.

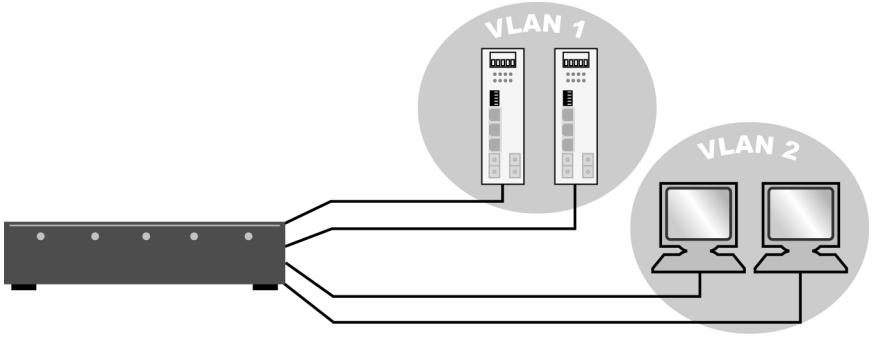
Broadcasting can be very useful. However, if the domain created in the network design is too large, a broadcast can create such a large amount of traffic that delays result. Some types of broadcast data may cause more delays than others, but the delays impact the performance of every device on the network. Limit the size of the broadcast domain with a router or intelligent switch that controls the delay from excessive broadcasts.

Using components such as routers to delineate broadcast domains can improve overall performance on a network. Routers between multiple LANs form logical broadcast domain boundaries. Since routers filter network traffic, a router can be configured to forward only specific broadcasts to other domains. Using a router for this process may add time, but increase the efficiency of transmission.

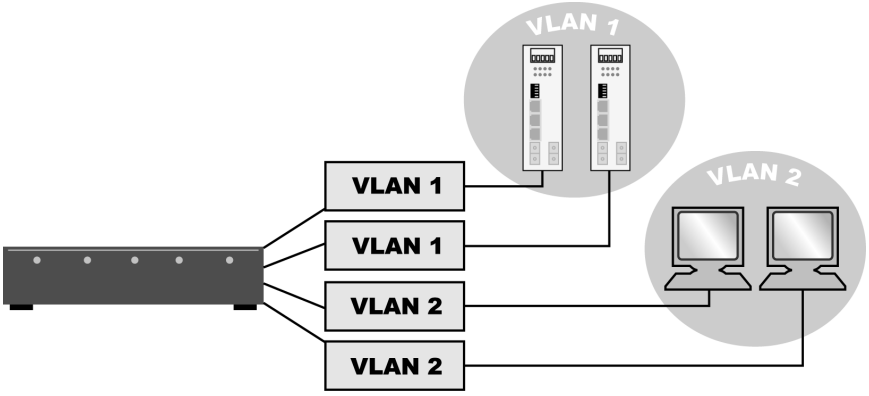
VLANs

A virtual LAN groups devices that may be in different physical locations into a virtual network, sharing resources, servers and other devices among a workgroup. Using a VLAN to segment traffic can increase network performance by reducing the size of collision domains and of traffic loads. It offers a flexible and less expensive way to modify groups in an environment that could change. The grouping also adds consistency to addressing and protocols, an advantage to the administrator, and needs less local server resources. A VLAN adds security safeguards as well.

There are several ways of grouping devices into a VLAN. Port-based VLANS are end-stations that are grouped by ports on a switch. If they are plugged into certain end ports, they belong to the same group. VLAN ports can be configured using intelligent switches that support VLAN configurations. Another type of VLAN configuration is protocol VLAN (PVLAN), in which the switch automatically looks at all ports and groups end-stations by protocol. End-stations can also be grouped by IP network address. Once an IP address is assigned to an end-station, it is placed in a specific VLAN.



End-stations can also be grouped on the basis of their IP addresses. After the IP address is assigned to an end-station, it is placed into a specific VLAN.



VLANs can be implemented on layer 3 switches (see *p. 60*) to create multiple broadcast domains, similarly to routers. The switching engine can then route from one VLAN to another, improving performance on the LAN.

Some limitations of VLANs include those on the number of broadcasts and Ethernet addresses and constraints on ports

Wireless IP

Wireless communication (IEEE 802.11a/b/g) allows mobile communications without the expense of cable runs or fixed-location maintenance. It does not replace wired networks; it does allow a single device to access the network from various locations. Wireless technology for industrial environments must create the same reliability, performance, and redundancy that exist today with wired networks.

LAN Hardware

Summary

An overview of the hardware used on a local area network is useful in planning a robust network for your industrial application. The following discussion gives a brief overview and some recommendations for the LAN hardware you should use to construct a Transparent Ready industrial Ethernet application (see *p. 77*).

Hardware and Its Operation Layer

The following table shows on which layer each hardware element falls, according to the OSI model (see *p. 124*):

Layer	Layer Number	Hardware
Application	7	gateway (If the gateway also converts protocol)
Network	3	routers/gateways, layer 3 switches
Data link	2	switches
Physical	1	hubs

Hubs (Repeaters)

A hub is an active device with multiple ports that interconnect devices and extend the network length. In general, hubs are plug-and-play devices that require no configuration. Hubs are transparent to other devices and are essentially repeaters that extend network segments. They receive information through any of their ports and pass along that information to all of their other ports. A limited number of hubs can be cascaded to extend the length of the network.

Devices interconnected by hubs are in the same collision domain—they are in the same network segment where information packets can collide. Thus, hub devices decrease network efficiency.

Switches

Switches are active devices used to interconnect devices and to extend network length. Unlike hubs, switches receive information through any of their ports and forward that information only to the port where the target device of the incoming information is connected. An unlimited number of switches can be cascaded to extend the length of the network.

Switches are transparent for the devices in the network. They offer many features to manage traffic and to provide security (see *p. 137*).

Switches break up collision domains so that devices interconnected by switches are in different collision domains.

Types of Switches

There are two types of switching—*cut-through* and *store-and-forward*.

- Cut-through switching begins to forward a packet once it is received, which can cause network disruption if the packet is bad.
- Store-and-forward switching waits for the entire packet to arrive and checks the packet for corruption before forwarding it out the correct port. This prevents corrupt packets from being forwarded across the entire network. A store-and-forward switch also stops a corrupt packet at the first switch it reaches after it has been corrupted. The time delay for the process is minimal, less than 1 ms on an industrial network.

Store-and-forward switches are recommended by Schneider Electric for automation networks.

Transceivers

Transceivers change the physical medium: in most of the cases that transition is between copper and fiber optic.

Bridges

A bridge has been used to connect two LAN segments with different protocols (Ethernet, Token-ring) or to connect two LANs, using Ethernet addresses. However, because bridges supply lower throughput performance, lower port density, higher transport cost, and less flexibility, switches are recommended for use over bridges.

Routers (Gateways)

An Ethernet router is also known as gateway or default gateway. Routers connect two separate networks. They create or maintain a table of the available networks and use this information to determine the best route for a given data packet from the source network to the destination network.

Routers can be used to break up broadcast domains.

Layer 3 Routing Switches

A layer 3 switch is a router implemented in hardware. It functions the same as a router but at an increased speed.

Other LAN Considerations

Summary

Below are some additional considerations for planning a robust industrial application network.

Full-Duplex vs. Half-Duplex

Schneider Electric recommends the use of full-duplex switches wherever possible. Full-duplex switches:

- give greater bandwidth (100 MB in both directions on certain networks)
- allow a device to send responses while receiving additional requests or other traffic
- result in less delays and errors with a device

When to Use a Switch

Switches should always be used in the design of your new network. They offer more intelligence than hubs at an equal or lesser cost.

The industrial switches available today work reliably under extreme conditions such as with electromagnetic interference, high operating temperatures, and heavy mechanical loads. Protect industrial switches by using field-attachable connectors up to IP67 (see *p. 74*) and redundant ring cabling.

Bandwidth

10 MB of bandwidth can be used for smaller end devices, but not for links to PLC/SCADA or to main network links.

100 MB is adequate for most automation systems.

1 GB is useful for the main network link. This capacity is not required, but ensures that more bandwidth is available if needed. 1 GB is necessary if other services share the network with the automation system.

WAN Technologies and Network Design

Summary

Several LANs that reside in widely separate physical locations can be joined into a Wide Area Network WAN. The WAN usually uses leased services for the connection. These may include;

- point-to-point leased lines
- circuit switching
- packet switching
- virtual circuits
- dial-up

WAN technologies function at the lower three layers of the OSI model (see *p. 124*): the physical layer, the data link layer, and the network layer.

When planning a Transparent Ready industrial Ethernet application, some factors you should consider about your WAN include the size and locations of the proposed network, the amount of traffic and the cost and speed of various commercial transmission services.

Point-to-Point Links (Leased Lines)

Point-to-point links furnish a single, pre-established WAN communication path from your site through a service provider's network to your remote network. The service provider dedicates wiring and bandwidth to meet the needs of your enterprise. Cost is dependent on how much bandwidth you require and the distance between connection points.

Circuit Switching

A router can initiate circuit-switched connections when they are needed, then disconnect the circuit when the communication is complete. The cost depends on the time that the circuit is used, making circuit switching a popular backup solution for other WAN technologies.

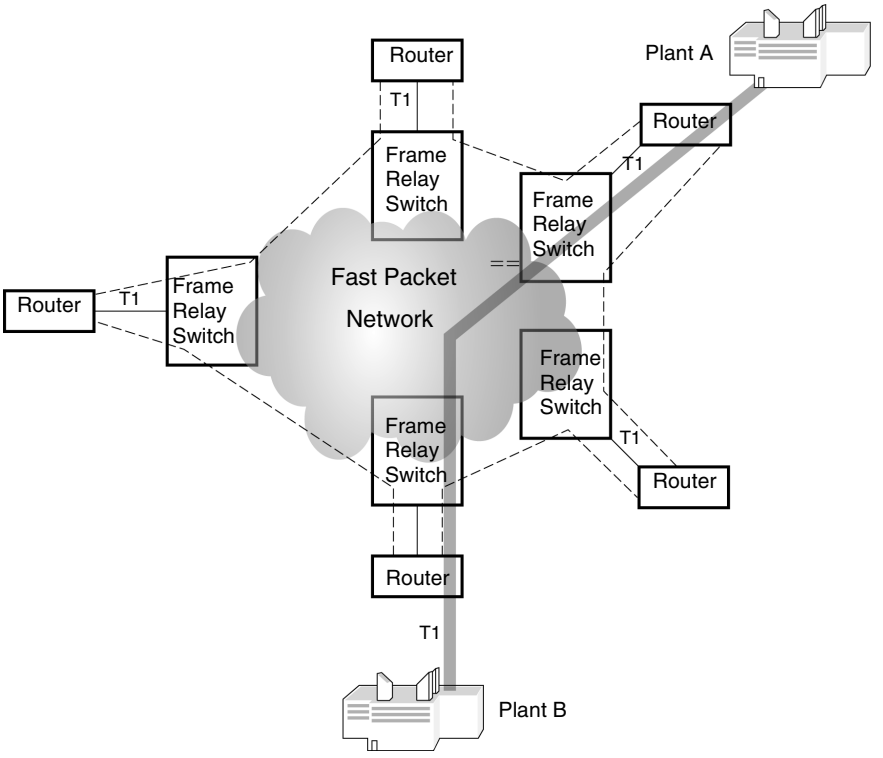
ISDN is one example of this cost effective technology. When used as a backup, routers can be configured to reroute traffic automatically if other WAN lines fail. ISDN supports data transfer rates of 64 kb/s. There are two types of ISDN:

- BRI, a basic service, comprises two 64 kb channels and one D-channel for transmitting control information
- PRI, for users with requirements for greater capacity, comprises 23 B-channels and 1 D-channel (U.S.) or 30 B-channels and 1 D-channel (Europe).

Packet Switching

Packet switching involves sharing resources at a service provider. The service provider allocates portions of a line or of virtual circuits for the use of your enterprise. Packet switching breaks up the packets and labels them individually, sends them sequentially over the network by the most expedient route, and reassembles them at the destination. It is more efficient and cost-effective for the carrier, making the cost to the user less expensive than dedicated services. The most common examples of packet-switched WAN technologies are frame relay, ATM, and MPLS.

Frame relay (which is based on packet-switching technology) supports data transfers rates of T-1 (1.544 Mb/s) and T-3 (45 Mb/s). Frame relay can provide a cost-effective solution for industrial applications.



Virtual Circuits

Virtual circuits are logical circuits created within a shared network. There aretwo kinds:

- switched virtual circuits (SVCs), which are dynamically established on demand and terminated when transmission is complete
- permanent virtual circuits (PVCs), a more expensive option for situations where data transfer between devices is constant

Dial-up Services

Dial-up services for a WAN can be an economical solution when your enterprise does not generate a lot of transmission traffic. Dial-up is also frequently used as a backup for other WAN technologies. Network managers can perform remote troubleshooting on a modem connected over an inexpensive dial-up line to a router if the main link is down.

WAN Hardware

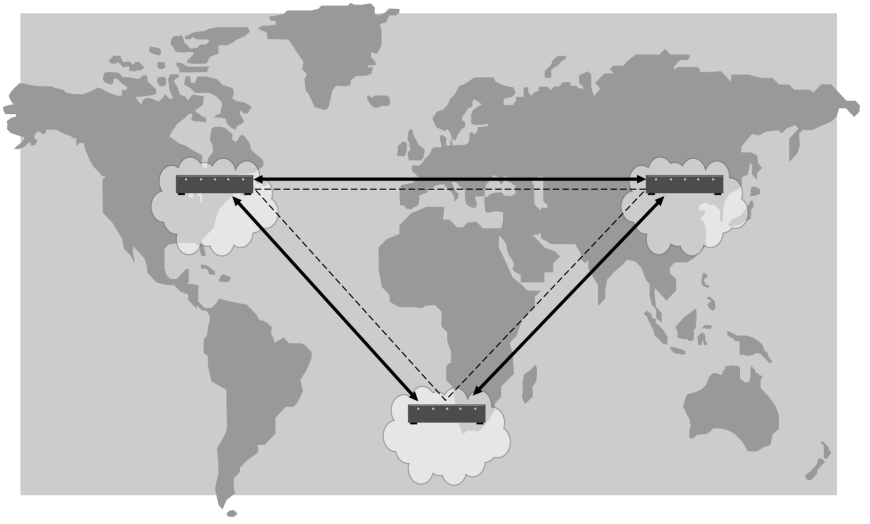
Summary

In order to connect from your network to other networks, some devices are needed:

- routers
- WAN switches
- access servers
- modems
- CSU/DSUs
- ISDN terminal adapters

Routers

A router is a logical switch that joins your network to the WAN and to connect from the WAN to your other network location. There is a router at each end of the WAN. Some routers may have the physical connection inside, but sometimes the physical connection device is external.



WAN Switches

Switches have layer 3 capabilities, which combine the advantages of switching and routing in a single device.

Access Servers

Access servers allow users to have dial-in and dial-out connections (*p. 144*).

Modems

Modems convert analog and digital signals and support connections to the network over voice-grade telephone lines. They can be built into other network components or purchased separately.

Three device options may be used to plug into a router:

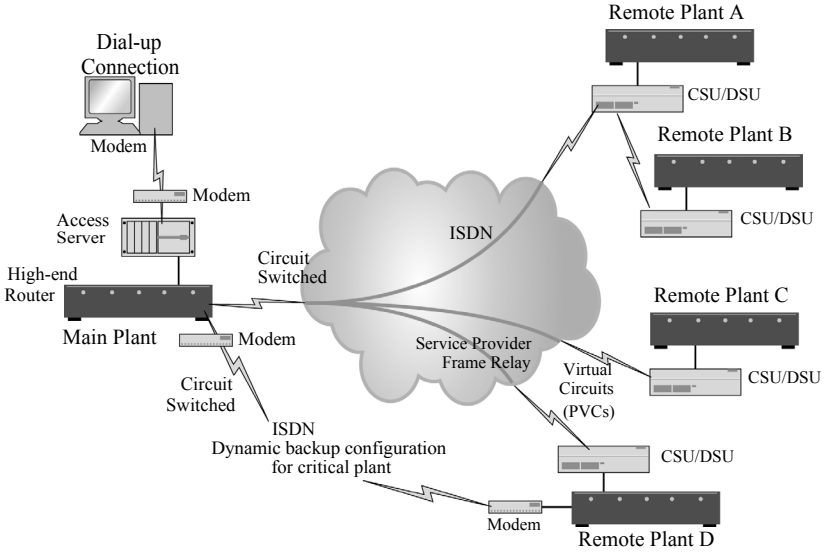
- modems
- CSU/DSUs
- ISDN terminal adapters

CSU/DSU hardware connects to a router to provide the connection to a digital network such as a T1 line. This hardware may connect as an external component or may be built into more advanced network components. Service providers often offer CSU/DSUs; if not, they can help you to configure your CSU/DSU properly to work with their line configuration.

An ISDN terminal adapter is modem used to connect ISDN basic rate interface (BRI) connections to a router. These adapters may be separate devices or built into a router.

WAN Topology

The diagram below shows a WAN consisting of a main site connected to several remote sites.



The main plant is connected to the remote plants C and D by a packet-switched frame relay connection using virtual circuits (PVCs in this case). The main plant is connected to remote plant A by ISDN lines. There is one critical site (Remote Plant D) that is also connected with a circuit-switched ISDN connection acting as a backup to the frame relay link. This IDSN connection is dynamically configured on the high-end router to connect only if the frame relay connection fails. A dial-up access server is also depicted (top left); it supports network management troubleshooting from remote locations in case all WAN connectivity to the main site is lost. Other WAN-specific hardware includes routers, modems, CSU/DSUs (at Remote Plants A,B, C and D), and an ISDN terminal adapter (at Remote Plant D).

2.3 Environmental Requirements

At a Glance

Overview

A Transparent Ready industrial Ethernet network supports the connection of industrial automation devices with Ethernet connectivity (PLCs, I/O, sensors, actuators, etc.) and industrial Ethernet infrastructure devices (cables, connectors, switches, hubs, etc.)

Schneider Electric proposes three environmental categories:

- office
- light industrial
- heavy industrial

This section describes the environmental requirements for an industrial Ethernet network.

Industrial refers to extreme environmental conditions (mechanical, climatic and ingress protection) to which the devices are exposed, and to noise immunity variables.

An industrial Ethernet must have predictable performance and a higher level of user friendliness under these extreme conditions.

What's in this Section?

This section contains the following topics:

Topic	Page
Environmental Standards Summary	68
Mechanical Requirements	69
Climate Protection Requirements	71
Ingress Protection Requirement	73
Electromagnetic Emission and Immunity Requirements	76

Environmental Standards Summary

Standards for Environmental Variables

The value range for a system's environmental variables (for example, temperature as a climate variable) is defined in industry standards set by UL, CE, IEC, CSA CENELEC, and others (see *p. 69*).

Even though many standards are international and globally accepted, efforts continue among the major standards organizations to reconcile existing standards and create new ones that agree with each other. Standards often differ from region to region, application to application, and device to device. Schneider Electric recommends that you take this into account when designing your Transparent Ready network.

Industrial and Telecommunications Standards

There are two additional concerns that relate to industrial Ethernet standards.

- Information Technology and Telecommunication groups such as TIA define standards for industrial Ethernet in addition to the traditional industrial standards organizations.
- Unlike industrial automation standards, standards for industrial Ethernet infrastructure devices (hubs, switches, routers, etc.), cables, and connectors not yet are clearly defined. Many industrial Ethernet infrastructure devices have adopted the standards in use for industrial automation devices (PLCs, I/O, etc.) and present these standards as appropriate for Ethernet devices.

Standards Compliance

This section attempts to bring together the recommendations for environmental safety set forth by the emerging industrial Ethernet standards and the Information Technology and Telecommunications standards. In addition to the recommendations, it is important to note:

- When you design an industrial Ethernet installation, you must comply with the regulations set forth by your regional standards organizations, both for the types of devices you plan to use and the applications you plan to target. These standards usually provide well-defined rules and guidelines for industrial automation devices.
- For cables and connectors, emerging standards are being defined. Industrial Ethernet organizations such as Modbus, IDA, and IAONA provide recommendations for cables and connectors. Other topics in this section reference their ongoing work in cable and connector standardization.

Mechanical Requirements

Introduction

Mechanical requirements apply to any mechanical, electrical, or electronic component or assembly of components. Tests and ratings for mechanical compliance with standards include the following:

- shock
- vibration
- tensile strength
- flexing
- crush
- impact

Shock Requirements

The following table shows the recommended allowable degrees of shock for an industrial Ethernet.

Environment	Shock Limits	Reference
Light Industrial Environment (Light Duty)	15 g/11 ms (3/axis in both directions	IEC 60068-2-27 (Environmental testing. Part 2: Tests. Test Era and guidance: Shock EN 60068-2-27
Heavy Industrial Environment (Heavy Duty)	20 g/11 ms (3/axis in both directions	IEC 60068-2-27 27 (Environmental testing. Part 2: Tests. Test Era and guidance: Shock EN 60068-2-27

Vibration Requirements

Vibrations are defined as mechanical oscillations produced by movements of a member or body from its rest position at regular or irregular time periods. Vibration can result in equipment damage, loss of control in equipment, and reduced efficiency in machine operation.

The following table shows the recommended allowable degrees of vibration for an industrial Ethernet.

Environment	Shock Limits	Reference
Light Industrial Environment (Light Duty)	2 g @ 10 - 500 Hz	IEC 60068-2-6 (Environmental testing. Part 2: Tests. Test Fc: Vibration (sinusoidal) EN 60068-2-6
Heavy Industrial Environment (Heavy Duty)	5 g @ 10 - 500 Hz	IEC 60068-2-6 (Environmental testing. Part 2: Tests. Test Fc Vibration (sinusoidal) EN 60068-2-6

Tensile Strength Requirements

The following table shows the recommended degree of tensile strength acceptable for industrial Ethernet cables.

Environment	Tensile Strength Requirement	Reference
Light Industrial Environment (Light Duty)	75/100/200 N for 1 min	IEC 60966-1
Heavy Industrial Environment (Heavy Duty	100/200 N for 1 min	IEC 60966-1

Flexing Requirements

The following table shows the recommended degrees of flexing allowable for industrial Ethernet cables.

Environment	Flexing Requirement
Light Industrial Environment (Light Duty)	5 N 1000 operations +/-90 degrees
Heavy Industrial Environment (Heavy Duty	5 N 1000 operations +/-90 degrees

Crush Requirements

The following table shows the recommended allowable degrees of crush for an industrial Ethernet cable.

Environment	Crush Requirement
Light Industrial Environment (Light Duty)	ISO/IEC is writing a draft standard document which has not yet been released.
Heavy Industrial Environment (Heavy Duty)	

Climate Protection Requirements

Introduction

Climate requirements for an industrial Ethernet include:

- ambient temperature during operation
- storage temperature
- humidity
- UV exposure

Temperature Requirements

Temperature can affect industrial automation devices and Ethernet infrastructure components such as cables, connectors and accessories in many different ways.

Extremes in temperature can affect performance. For example, extreme cold can cause cable to become stiff, brittle and hard to work with, whereas elevated temperature can soften or even melt the plastic used in a cable. Attenuation in the standard off-the-shelf CAT 5E cable increases at a rate of 0.4% per degree Celsius, above 20.

The ambient temperature is the temperature of the environment surrounding the device. Measure the ambient temperature for a device at 30 to 40 cm from the exterior surface of the device, in order to allow for the effect of heat and airflow in the immediate vicinity.

The two tables that follow show the ambient temperature ranges for operation and storage. If the ambient operating temperature is within the given range while the device is in operation, that device is being used within its temperature specifications.

Operating Temperature Table

Environment	Operating Range	Reference
Light Industrial	0 to 60 degrees C	IEC 60654-1
Heavy Industrial	-20 to +85 degrees C	IEC 60654-1

Storage Temperature Table

Environment	Operating Range
Light Industrial	-25 to +70 degrees C
Heavy Industrial	-25 to +70 degrees C

Other Environmental Factors

Humidity and UV exposure can also affect cable performance.

The tables below show the acceptable humidity range (by percentage) for operation and the acceptable number of hours of UV exposure.

Humidity Table

Environment	Humidity
Light Industrial	5 to 95% noncondensing
Heavy Industrial	0.1 to 95% noncondensing

UV Exposure Table

Environment	UV Exposure
Light Industrial	3000 hr
Heavy Industrial	6000 hr

Ingress Protection Requirement

Introduction

Ingress is the ability of solid foreign bodies such as dust, water, moisture, and other pollutants to enter an industrial equipment enclosure. Ingress protection refers to the ability of the enclosure to keep these objects out. This requirement also includes keeping people away from moving parts within the enclosure.

Two types of regulations define ingress protection variables:

- degree of pollution
- degree of protection

Degree of Pollution

Pollution, such as moisture or dust, on the surface of devices can reduce their insulation capability. The IEC 1010 standard specifies different types of pollution environments. Heavily polluted environments require more insulation. Another option is to create clean micro-environments for circuits and sensitive equipment using enclosures, encapsulating methods, and hermetic sealing.

Four levels of pollution are defined by standard IEC 60664-1 (*Insulation coordination for equipment within low-voltage systems - Part 1: Principles, requirements and tests*):

Pollution Level	Description
Grade 1	Nonpollution or only dry, nonconductive pollution. This type of pollution has no electromagnetic or other influence.
Grade 2	Normally only nonconductive pollution. Temporary conductivity caused by condensation may also occur.
Grade 3	Conductive pollution or dry nonconductive pollution that becomes conductive due to condensation. Grade 3 pollution occurs in industrial environments and construction environments that are considered harsh.
Grade 4	Pollution that generates persistent conductivity caused by conductive dust, rain, or snow.

Pollution Table for Industrial Ethernet

The following table shows the recommended levels of pollution allowed for industrial automation devices and Ethernet infrastructure components:

Environment	Pollution Level Allowed	Reference
Light Industrial (Light Duty)	Grade 2	IEC 1010
		IEC 60664-1
Heavy Industrial (Heavy Duty)	Grade 3	IEC 1010
		IEC 60664-1

Degree of Protection: IP Rating Code

The degree of protection is defined by the IEC 60529 standard. This standard describes an international classification system that uses the letters *IP* (for *ingress protection*) followed by two or three digits. This IP code defines the effectiveness of the seal on electrical equipment enclosures against the intrusion of solid foreign objects such as dust, tools, fingers, etc.

The first (leftmost) digit in the IP code indicates the degree to which persons are protected against contact with moving parts (excluding smooth rotating shafts), as well as the degree to which the equipment is protected against the entry of solid foreign objects into its enclosure.

First Digit	Degree of protection: Solid objects
0	no special protection.
1	Protection from a large human body part, such as a hand, and from solid objects greater than 50 mm in diameter. It has no protection from deliberate access.
2	Protection against fingers or other objects not greater than 80 mm in length and 12 mm in diameter.
3	Protection from entry by tools, wires, and other solid objects with a diameter or thickness greater than 1.0 mm.
4	Protection from entry by solid objects with a diameter or thickness greater than 1.0 mm.
5	Protection from the amount of dust that would interfere with the operation of the equipment.
6	Dust-tight enclosure.

The second digit of the IP code indicates the degree of protection the equipment has against the harmful intrusion of water and moisture in varying forms.

Second Digit	Degree of protection: Moisture
0	No special protection.
1	Protection from dripping water.
2	Protection from vertically dripping water.
3	Protection from sprayed water.
4	Protection from splashed water.
5	Protection from water projected from a nozzle.
6	Protection against heavy seas or powerful jets of water.
7	Protection against immersion.
8	Protection against complete continuous submersion in water.The end user must specify submersion depth and time. The requirement must be greater than IP67.

A third digit is sometimes used if there is only one class of protection, and an X is used for one of the digits. For example, IPxI indicates that the equipment is protected against dripping water only.

Recommended Degrees of Protection for Industrial Ethernet

Environment	Degree of Protection Recommended	Reference
Light Industrial (Light Duty)	IP20	IEC 60529 (Degrees of protection provided by enclosures (IP code)
		EN 60529
Heavy Industrial	IP67	IEC 60529 (Degrees of protection provided by enclosures (IP Code)
		EN 60529

Electromagnetic Emission and Immunity Requirements

Introduction

There are two types of EMC requirement:

- emission: how much EMC a product or cable can emit.
- immunity: the degree of tolerance for EMC that a product or cable has

The standards that apply depend on the environment for which you are designing your Transparent Ready system.

The two main EMC standards organizations are IEC and CENELEC. The two main international standards for electromagnetic emission and immunity are:

- IEC 61000-6-2: 1999 *Electromagnetic compatibility - Part 6-2: Generic standards - Immunity for industrial environments*
- IEC 61000-6-4: 1997 *Electromagnetic compatibility - Part 6: Generic Standards - Section 4: Emission standard for industrial environments*

IEC 1000-4 Standard

The IEC 1000-4 standard establishes a common reference for evaluating the performance of industrial-process measurement and control instrumentation when exposed to electric or electromagnetic interference. The standard describes interference susceptibility tests that demonstrate the ability of equipment to function correctly in working environments.

When determining the type of tests to run, base your choices on the types of interference to which your equipment is exposed when installed. Take the following factors into consideration:

- the method by which the electrical circuit and shields are tied to earth ground
- the quality of the shielding
- the environment

Sections IEC1000-4-2 through 1000-4-5 (see *p. 485*) are discussed in more detail later in this manual.

2.4 Selection of Industrial Ethernet Components

At a Glance

Overview

This section provides information about the proper selection of industrial Ethernet components. It discusses recommended connectors for office or light industrial use and for heavy industrial use. Copper cables for an industrial Ethernet network and the tooling needed to manufacture the cables are also discussed.

What's in this Section?

This section contains the following topics:

Topic	Page
Ethernet Copper Cables	78
Fiber Optic Cabling	82
10/100BaseF Physical Layer Specification	86
Ethernet Connectors for Copper Networks	87
Fiber Optic Connectors	90
Recommended Infrastructure Devices for Industrial Ethernet	92

Ethernet Copper Cables

Introduction

Ethernet cables route transmitted signals from one device to another. When you make cables, you need to know what types of devices you will be connecting. Most Ethernet systems use routers, switches, and hubs to manage information flow. These devices require a different type of cable than the type installed between two end devices that communicate with each other directly.

Transparent Ready's industrial Ethernet must use shielded CAT 5E twisted pair cables, or better.

Twisted Pair Cables

Twisted pair cabling is a common form of wiring in which two conductors are wound around each other to cancel electromagnetic interference (crosstalk). The number of twists per meter make up part of the specification; more twists produce less crosstalk.The twisting of pairs, the quality of the conductive material, the type of insulator, and the shielding largely determine the rate at which data can be transmitted.

Classification and Cable Categories

LAN cables are generically called unshielded twisted pair (UTP) and are identified with a category rating. The American National Standards Institute/Electronic Industries Association (ANSI/EIA) standard 568 is one of several standards that specify categories of twisted pair cabling systems (wires, junctions, and connectors) in terms of the data rates that they can sustain effectively. The specifications describe the cable material and the types of connectors and junction blocks needed to conform to a category.

Category	Maximum data rate	Usual application
CAT 1	up to 1 Mb/s (1 MHz	Traditional unshielded twisted-pair telephone cable that is suited for voice. It is not recommended for network use.
CAT 2	4 Mb/s	Unshielded twisted-pair cable certified for data transmissions up to 4 Mbit/s. This cable has four twisted pairs. This cable should not be used for high-speed networking.
CAT 3	16 Mb/s	Rated for signals up to 16 MHz and supports 10 Mbit/s Ethernet, 4 Mbit/s token ring, and 100 VG-AnyLAN networks. The cable is twisted for noise immunity. This cable is installed at many sites as telephone cabling.
CAT 4	20 Mb/s	Rated for signals up to 20 MHz and is certified to handle 16-Mbit/s token ring networks. The cable has four pairs.
CAT 5	100 Mb/s 1000 Mb/s (4 pairs)	Rated for signals up to 100 MHz at a maximum distance of 100 m. Ethernet 100Base-TX, FDDI, and ATM at 155 Mbit/s use this cabling. It has low capacitance and exhibits low crosstalk due to the high number of twists/ft. The predominant cable in new buildings since the early 1990s. No longer supported; replaced by 5E.

Category	Maximum data rate	Usual application
CAT 5E	up to 350 Mb/s	(Enhanced CAT 5) has all the characteristics of CAT 5, but is manufactured with higher quality to minimize crosstalk. It has more twists and is rated at frequencies up to 200 MHz, double the transmission capability of CAT5. However, at these frequencies, crosstalk can be a problem, and the cable does not have shielding to reduce crosstalk. This cable is defined in TIA/EIA-568A-5 (Addendum 5).
CAT 6	up to 400 MHz	Designed to support frequencies over 200 MHz using specially designed components that reduce delay distortion and other problems. The TIA and ISO are cooperating on this category.
CAT 7	600-700 MHz	Designed to support frequencies up to 600 MHz. Each pair is individually shielded, and the entire cable is surrounded by a shielded jacket. Connectors are expected to be specially designed proprietary components. TIA and ISO are cooperating on this category.

The two most widely installed categories are CAT 3 (for 10Base-T) and CAT 5 (for 100Base-T). While the two cables may look identical, CAT 3 is tested to a lower set of specifications and can cause transmission errors if pushed to faster speeds. CAT 3 cabling is near-end crosstalk-certified for only a 16 MHz signal; CAT 5 cable must pass a 100 MHz test. CAT 5E has recently replaced CAT 5 as the prevalent standard.

Twisted Pair Cable Shielding

There are two main types of twisted pair: shielded twisted pair (STP) and unshielded twisted pair (UTP).

Usually STP and UTP cables have two pairs of cables (4 conductors). Screened twisted pair (ScTP) is four-pair 100 Ω UTP, with a single foil or braided screen surrounding all four pairs to minimize EMI radiation and susceptibility to outside noise. ScTP is also called foil twisted pair (FTP), or screened UTP (sUTP). It can be thought of as a shielded version of the CAT 3, 4, and 5 UTP cables. It may be used in Ethernet applications in the same manner as the equivalent category of UTP cabling.

Note: Transparent Ready's industrial Ethernet must use shielded CAT 5E cables.

Other Cable Characteristics

UTP and STP cables comes in two forms: solid and stranded. *Solid* refers to the fact that each internal conductor is made up of a single solid, wire. *Stranded* means that each connection comprises multiple smaller wires. The only benefit of using stranded cable (which is typically more expensive) is its smaller bend- radius (you can squeeze it around tighter corners with lower loss). In most other respects, the performance of the two cable types is the same.

Physical Layer Specification

The following table provides a summary of some of the various physical layer specifications defined for Ethernet.

Standard	Data Rate	Connector Technology	Medium	Maximum Cable Segment Length	
				Half-Duplex	Full-Duplex
10Base-T	10 Mb/s (20 Mb/s in optional full duplex)	RJ45	two pairs of 100 Ω CAT 3 or better UTP cable	100 m	100 m
100Base-TX	100 Mb/s ((200 Mb/s in optional full-duplex mode)	RJ45	two pairs of 100 Ω CAT 5 UTP cable	100 m	100 m
1000Base-T	1 Gb/s	RJ45	four pairs of 100 Ω CAT 5 or better cable	100 m	100 m

100Base-TX supports transmission over up to 100 m of 100 Ω CAT 5 UTP cabling. CAT 5 cabling (used with 100Base-T) is a higher grade wiring than CAT 3 (used with 10Base-T). It is rated for transmission at frequencies up to 100 MHz. CAT 3 cabling supports transmission only up to 16 MHz. The 100Base-TX standard supports the option of using 150 Ω STP cabling.

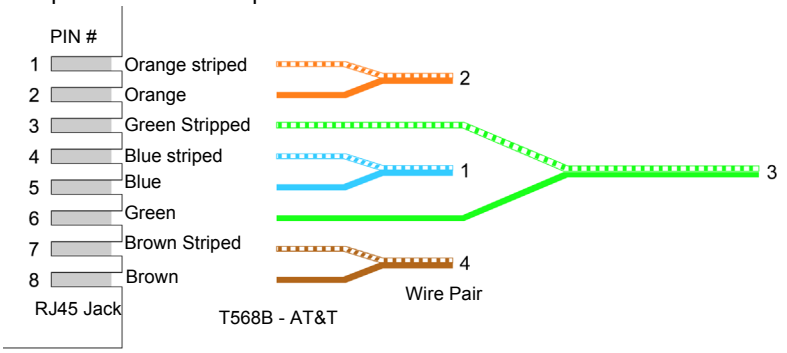
Cable Color Specifications

The EIA/TIA-568B standard defines the pinout for wires in RJ45 8-pin modular connectors plugs and jacks. It also defines the color code for the 8 wires in the four pairs. (The color coding specification is independent of the type of network.) Refer to the EIA/TIA-568B standard for all pinout specifications.

The colors defined for the 4 pairs/8 cables are:

Pair 1	Blue/White with Blue stripe
Pair 2	Orange/White with Orange stripe
Pair 3	Green/White with Green stripe
Pair 4	Brown/White with Brown stripe

The pinout color code specified for the RJ45 connector is shown below.



Schneider recommends that the jacket of the cable be green RAL 6018.

Difference between EIA/TIA 568A and EIA/TIA 568B

The difference between the color codes is that pair 2 (orange) and pair 3 (green) are interchanged. The EIA/TIA 568B standard is the most widely used.

Note: There is no difference between the two wiring schemes, in connectivity or performance when connected from one modular device to another (jack to Patch panel, RJ-45 to RJ-45, etc.), so long as the two devices are wired for the same scheme (A or B).
Also, refer to Installation (see *p. 93*) for more detailed information regarding the installation of cabling.

Fiber Optic Cabling

Summary

Fiber optic cabling offers an alternative to copper wiring, replacing traditional UTP and STP cable. Typically, fiber optic cable is used for backbone networks in buildings and campuses. Improvements in fiber optic performance, connectivity, and testing make it the best choice for LAN connections across long distances, as for example between manufacturing plants or industrial facilities. Additional advancements in transceiver products and lower cable costs add to its attraction as a high-performance option.

Standards for Fiber Optic Cable

The existing TIA/EIA fiber optics standards do not define an architecture like the TIA/EIA 568-B and ISO/IEC 11801 standards. Instead, the fiber optic standards are written to apply to all fiber installations regardless of their location or use. Today, the same standards apply to all installations; there are no distinctions made for fiber cable suspended under water or in the air, inside or outside a building, used for backbone networks or installed in airplanes.

Fiber Optic Cable Technical Description

Fiber optic cable uses long, thin strands of ultra-pure glass (silica) or plastic that transmit light signals over long distances. The glass strands are very thin, about the size of a human hair, and are arranged in bundles called optical cables.

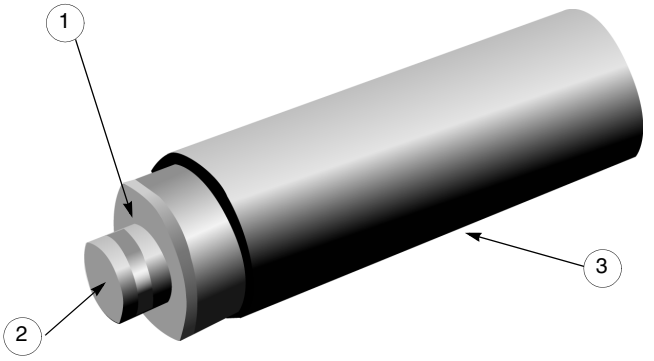
A fiber optic cable consists of a center glass core surrounded by glass cladding and a plastic jacket. Light photons are transmitted through the center core and reflected back along the sides by the reflective material of the cladding. A thick plastic jacket (strengthened with special fibers) surrounds and protects these two inner cores. In certain types of cable, the fiber can have a metal core that gives the cable additional strength.

Fiber optic cable has the ability to transmit signals over longer distances and at faster speeds than copper cable. Also, because fiber optic cable transmits light, it does not present the problems of electromagnetic interference associated with copper cabling. It is ideal for harsh industrial environments and outside connections between plants due to its high immunity to moisture, as well as to lighting.

Parts of a Fiber Cable

Typically, a fiber optic cable consists of three parts:

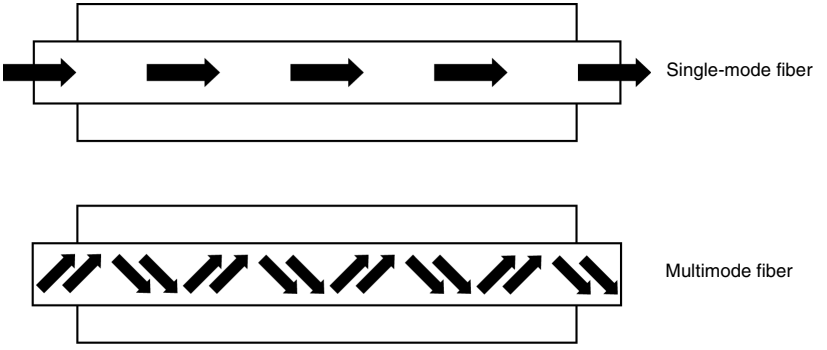
- core: thin glass center of the fiber that transmits light
- cladding: outer optical material that surrounds the core and reflects light back into the core
- buffer jacket: outer plastic jacket or coating that protects the fiber from damage and moisture



1 cladding
2 core
3 buffer coating

Fiber Cable Types: Introduction

A light signal can propagate through the core of a fiber along a single path (called single-mode fiber) or multiple paths (called multimode fiber).



Fiber Cable Types: Multimode Cable

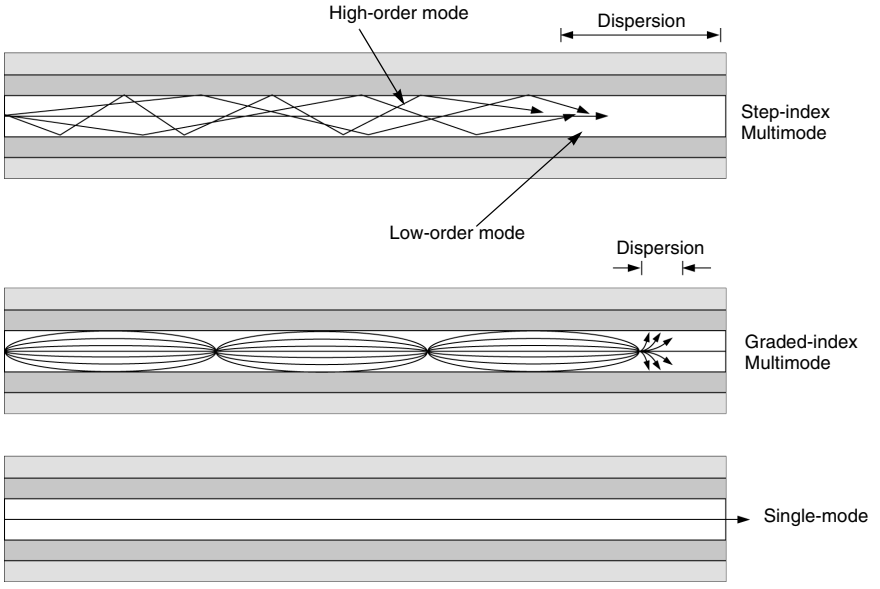
Multimode fiber has a large core diameter (about 2.5×10^{-3} in or 62.5 μm) and transmits infrared light (wavelength = 850 to 1300 nm) from light-emitting diodes (LEDs). Multimode fiber cable is most often used in LED-based LAN systems, campus networks and short distance metropolitan networks.

There are two types of multimode cable:

- Step-index: has an abrupt change between core and cladding; is limited to about 50Mb/s.
- Graded-index: has a gradual change between core and cladding; is limited to 1Gb/s.

Note: The core specifications for step-index and graded-index multimode cables are typically 50, 60.5 or 100 μm. The cladding diameter for step-index cable is 125 μm.
When cable is graded, the amount of refraction is reduced gradually outward from the core. Because light travels faster when refraction is lower, light travelling through the outer material travels faster than light at the center of the core.

The following illustration shows step-index multimode, graded-index multimode and single-mode cable:



Fiber Cable Types: Single Mode Cable

Single-mode fiber has a small core diameter (about 3.5×10^{-4} in or 9 μm) and transmits infrared laser light (wavelength = 1300 to 1550 nm). it provides only one optical mode that forces light along a linear path through the cable end and allows significantly more bandwidth than multimode. Single-mode fiber cable is often used in laser-based long-distance, interoffice LAN applications, cross-country networks, and international submarine links. SIngle-mode cables used for long-distance networks can include 100 to 800 fibers/cable.

Advantages of Single vs. Multimode

The advantages of single-mode fiber are a higher data capacity, low attenuation, and low fiber cost. It is the most expensive cable and is harder to handle, but has the highest bandwidth and distance ratings. The advantages of multimode fiber is a lower connection and electronics cost that can lead to lower installation costs.

Advantages of Fiber Optic Vs. Copper Cable

Fiber optic cable has several advantages compared to copper wire cable. Fiber optic cable is selected for use in backbones and other areas of LAN and Ethernet networks.

The advantages are:

- Lower cost: Optical cable is less expensive to make than copper wire of an equivalent length.
- Higher information capacity: There are more optical fibers bundled in a cable, which means more information can flow over an optical cable than a copper cable of similar diameter.
- Less signal degradation: Optical fiber has less signal loss over equivalent distances than copper wire.
- Thinner, more flexible and light weight: Optical fiber can be drawn thinner than copper wire, making it lighter, more flexible, and easier to position through small spaces.
- Low power: Optical fiber signals degrade less and therefore require lower-power transmitters to boost signals.
- No disturbance or other risks: Because no electricity passes through optical fibers, there is no electromagnetic interference and no fire or earthing hazard.

10/100BaseF Physical Layer Specification

Introduction

10/100BaseF refers to specific physical layer specifications for fiber optic cable carrying Ethernet signals.

10Base-FL Cable Specification

The traditional Ethernet (10Mb/s) includes specifications for the 10Base-FL physical layer. 10Base-FL supports fiber optic cable backbones of up to 4 km. The TIA/EIA Commercial Building Wiring standard approves 10Base-FL for cross-connections between campus buildings. The 10Base-FL has a transmission rate of 10Mb/s (20Mb/s in optional full-duplex mode) and the maximum segment length is 2000 m. The typical cable is multi-mode fiber, 62.5/125 (62.5 μm fiber core with 125 μm outer cladding), 850 nm wavelength.

100Base-FX Cable Specification

The 100Base-FX physical layer specification is approved by the IEEE 802.3u standard for Fast Ethernet (100 Mb/s) over fiber optic cable. The 100Base-FL has a transmission rate of 100 Mb/s (200 Mb/s in optional full-duplex mode) and the maximum segment length is 2000 m (full-duplex). The typical cable is multimode (62.5 μm fiber core with 125 μm outer cladding), 1300 nm wavelength.

Schneider Optical Fiber Recommendations

For Transparent Ready industrial Ethernet applications, Schneider recommends the use of 62.5/125 type fiber, using the minimal amount and maximal quality of fiber. Schneider supports communications on wavelengths from 850 nm (for 10Base-FL) to 1300 nm (for 100Base-FX). The cable may contain other fibers or electrical conductors. The protection specifications for the cable must be compatible with your installation conditions.

Environment	Physical Layer	Recommended Fiber	Wave Length	Maximum Segment Length
Light and Heavy Industrial Environment	10Base-FL	62.5/125 (multimode)	850 nm	2000 m
	100Base-FX	62.5/125 (multimode)	1300 nm	200 m (full-duplex

Ethernet Connectors for Copper Networks

Summary

After a thorough analysis of market trends, industry proposals, and on-going standardization work, and in the absence of international standards for copper cabling in industrial Ethernet networks, Schneider Electric has defined the types of connectors to use in Transparent Ready industrial Ethernet products, as of this writing.

Schneider Electric recommends the RJ45 connector for use in office and light industrial environments (see *p. 67*) and the M12 4 pole with D-coding circular connector for use in heavy industrial environments.

Recommended Ethernet Copper Connectors

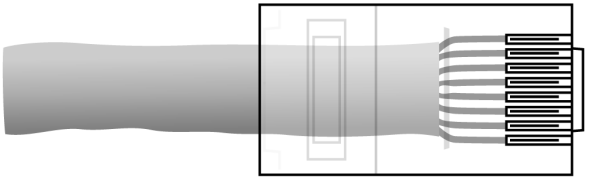
The following table lists specifications for the industrial Ethernet copper connectors recommended by Schneider Electric.

Environment	Connectors	General Specifications	Reference
Light Industrial (Light Duty)	RJ45		IEC 60603-7 and TIA/EIA 568B
		Pin assignment: ISO/IEC 8802-3	
		Pinout Color Coding: TIA/EIA 568B	
		Shielded	
Heavy Industrial (Heavy Duty)	M12 4 pole with D-coding		IEC 61076-2-101
		Shielded	

RJ45 Connector

As defined in the Ethernet IEEE 802.3 and the ISO/IEC 8802-3 standards, the connector specified for the Ethernet 10Base-T and 100Base-TX physical layers is the RJ45 (copper installations). *RJ* (registered jack) is defined in the United States Code of Federal Regulations.

The RJ45 is a connector used to terminate twisted pair cables. A typical RJ45 connector is shown here:

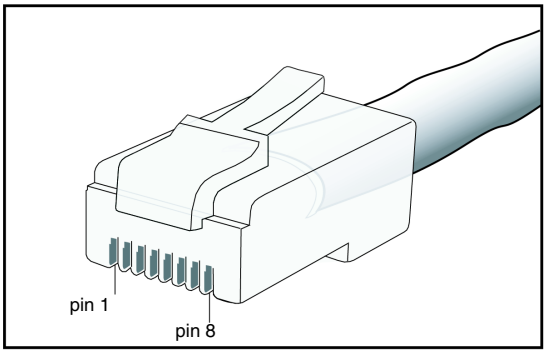


Shielded (or Screened) RJ45 Connector

Schneider Electric recommends shielded RJ45 connectors in office and light industrial environments, and shielded CAT 5E cables for 10Base-T and 100Base-TX industrial Ethernet networks. If you have devices that use shielded jack connectors and are externally grounded, the cable shield is grounded at both ends of the cable.

RJ45 Pins and Ethernet Signals

The RJ45 connector has 8 (eight) pins or electrical connections that are numbered 1-8 from left to right.



For Ethernet 10Base-T and 100Base-TX, the RJ45 pins are used as follows:

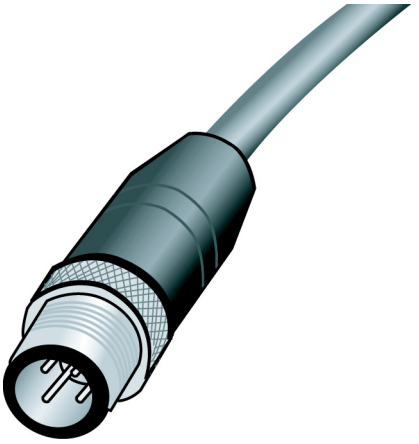
RJ45 pin	Ethernet Signal
1	Transmit + (TX+)
2	Transmit - (TX-)
3	Receive + (RX+)
4	Unused
5	Unused
6	Receive - (RX-)
7	Unused
8	Unused

When making Ethernet cables, if you plan to only use 2 pairs (4 conductors), you connect all of them. If you use 4 pairs (8 conductors), Schneider recommends that you connect them as suggested in the EIA/TIA 568B specification, even though pins 4, 5, 7, and 8 do not have signals assigned. For the recommended color coding based on the TIA/EIA 568B standard, please see *p. 80*.

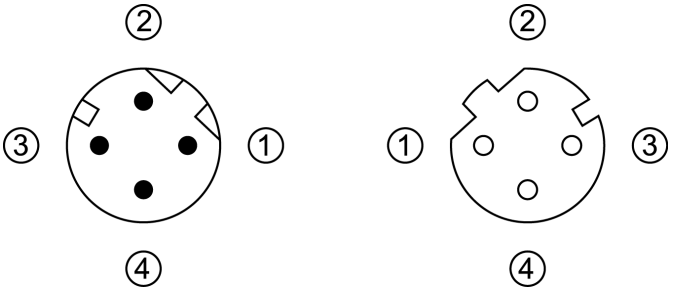
Note: When you use CAT 5/5e cabling, pins 4, 5, 6, and 8 are not required for 10Base-T or 100Base-TX physical layers.

M12 Circular Connectors

The use of M12 circular connectors is not yet a defined standard, although the M12 circular connector is used at the field bus level in many heavy-duty industrial applications. Schneider Electric recommends the M12-4 (4 poles) with D-coding for Transparent Ready Industrial Ethernet networks in heavy industrial environments.



M12 Circular Connector Pins and Ethernet Signals



For Ethernet 10Base-T and 100Base-TX, the M12 circular connector pins have the following designated Ethernet signals:

M12	Ethernet Signal
1	Transmit + (TD+)
2	Receive + (RD+)
3	Transmit - (TD-)
4	Receive - (RD-)

Fiber Optic Connectors

Development of Fiber Connectors

Several types of fiber connectors have been developed. The fiber connector (FC) was the first connector to use a 2.5 mm ceramic ferrule. The ferrule is the connector cap that surrounds the end of an optic sheath and creates the connection. The straight terminus (ST) connector was introduced slightly later. It had the same ceramic ferrule, but was easier to insert because of its lock. The subscriber connector (SC) appeared next and has gained popularity. The mass termination (MT) and the MT/RJ connectors are the most recent developments in the connector industry.

SC Connectors

The SC connector is becoming the most popular connector in use with fiber cable. It has a square front and is easier to install in confined spaces.

ST Connectors

The ST connector was introduced by AT&T. It is the most frequently found connector in installed fiber optic networks, since it has been the most popular connector to use in recent years. It has a barrel shape that looks similar to a BNC connector with a bayonet-like lock that makes it fast and easy to insert.

LC Connectors

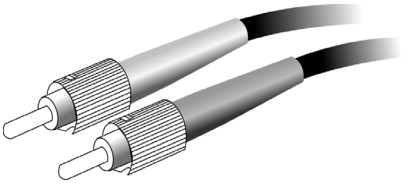
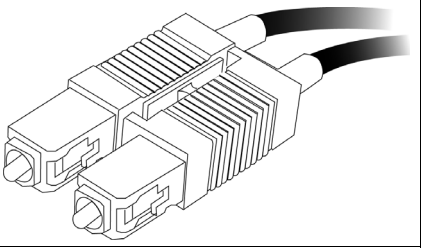
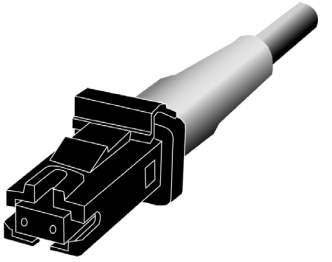
The LC connector resembles a small SC connector. It was developed by Lucent for use in telecommunications environments. It has been standardized in the EIA/TIA-604-10 standard.

MT/RJ Connectors

Small form factor (SFF) connectors like the MT connector are a more recent addition to the class of optical connectors. The MT (Mass Termination) connector refers to the 12 or 24 fibers that it connects. The name of its duplex cousin the MT/RJ refers to the RJ-45 style of copper connector it resembles.

Fiber Optic Connectors

Schneider Electric recommends the use of the following connectors for the Transparent Ready Industrial Ethernet:

Environment	Physical Layer	Recommended Connector	Appearance
Light industrial and heavy industrial environment	10Base-FL	ST	
	100Base-FX	SC	
	100Base-FX	MT-RJ	

Recommended Infrastructure Devices for Industrial Ethernet

Recommendations

Schneider Electric Recommendations for Use of Industrial Ethernet Infrastructure Devices	
General	Use switches as much as possible to eliminate collisions. increase performance and simplify network design. Avoid using hubs whenever possible. Understand network traffic and segment network properly. Follow environmental recommendations provided in this manual.
When high bandwidth availability is required	Use full-duplex switches (10Base-T/100Base-TX). Understand network traffic and segment network properly.
For applications where minimum application downtime is required	Use self-healing ring or redundant self-healing ring.
For networks that require basic level diagnostics (e.g. no link or failure of one P/S)	Use unmanaged switches with alarm relay.
For networks that require high-level services and traffic administration	Use managed switches.
For applications that require network discovery and monitoring	Use managed switches.
For applications that require interconnecting devices separated by long distances (> 100 m)	Use fiber optic products. Multimode fiber: Up to 2 km between nodes. Monomode fiber: Up to 15 km between nodes. Note: Depending on the fiber and the optical budget, could reach 4 km on multimode and 30 km on monomode.
For networks that require immunity to electromagnetic noise	Use products with fiber optic ports.
For applications that require physical medium change	Use transceivers or use switches with a combination of copper and fiber optic ports.
For applications that require external (IP67) mounting of the switch	Use IP67 switches and cables.

2.5 Installation

At a Glance

Overview

This section describes measures you can take to prevent electromagnetic interference (EMI) from seriously impeding your network or from causing intermittent problems that are difficult to diagnose. Earthing (also referred to as grounding), the equipotential bonding of equipment, cabinets, buildings, and the planning of cable runs within the site are discussed in detail, with a focus on measures to be taken for an industrial automation communications system.

What's in this Section?

This section contains the following topics:

Topic	Page
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Ethernet Copper Cable Types	105
Ethernet Copper Cable Tools	108
How to Make an Ethernet Cable	109
Cabling Administration	111
Cabling Documentation	112

EMC Installation Rules for Ethernet Networks

Introduction

When properly incorporated into the planning of your network, the following methods can help you avoid electromagnetic disturbances and create an EMC-compliant environment.

Protecting the Ethernet network from electromagnetic interference (EMI) is an issue that involves your complete installation. Although it is important to be concerned about EMI immunity throughout your entire system, this section describes only methods that apply to your Ethernet network. By equipotentially bonding, earthing, proper wiring, and shielding your site and equipment, you can significantly reduce a large percentage of EMI issues.

For more information on EMC, see the environmental requirements section (see *p. 67*).

For more information on EMI, see EMI (see *p. 489*).

Installation Measures to Combat EMI in Ethernet Networks

The following list describes key measures you need to consider in your installation in order to reduce EMI in an industrial Ethernet network:

- earthing and equipotential bonding
- EMC-compatible wiring and cable runs
- balancing circuits
- cable selection
- shielding
- filtering
- placement of devices
- placement of wires
- transposition of outgoing and return lines
- electrical isolation

Earthing and Equipotential Bonding Defined

Earthing is the method used to carry an electric charge to the ground (earth) along a conductive path. Examples of conductors include: a wire, metal conduit, or metal cabinet.

Equipotential bonding is the process of connecting conductive parts in order to create a low-resistance electrical contact for direct current and lower-frequency alternating currents. This interconnection spreads the flow of interference over multiple paths so that it avoids any one junction.

In most cases an equipotential bonding system is earthed. The flow of interference terminates in the earth. The flow of an electric charge is dispersed into the ground and away from sensitive equipment and communication lines. The EN 50310 standard requires buildings with information systems to be fitted with a common bonding network that consists of multiple conductive elements.

Equipotential Bonding

Introduction

Equipotential bonding creates an interconnection of conductive parts that disperses the flow of EMI disturbances over multiple paths, connecting to the earth through an earthing system. The design of an earthing system is determined by local conditions and requirements. The layout of your building and of all the machinery within it determines how simple or complex your earthing system needs to be.

The topics that follow describe at a high level what you can do to create equipotential bonding and earthing systems at your site so that it can be protected against EMI disturbance. For more details, see *p. 489*.

Earthing System Components

The typical earthing system consists of three components:

- *actual earth*: which conducts current into the ground through an earth electrode, a pipe, or a metal conductor
- *earthing main conductor*: a conductive system to which the earth and all necessary parts of the installation are connected
- *earthing conductors*: which connect parts of the installation to the earthing main conductor

Equipotentially Bonding Your Building

Introduction

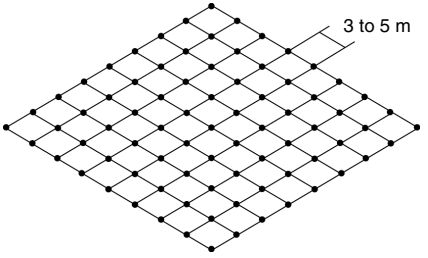
The EN 50310 standard requires buildings with telecommunications systems to be fitted with a common bonding network (CBN) that consists of multiple elements. This requires the creation of an earthing main conductor and the attachment of all metal structures and objects in the building to that main conductor. The CBN is then connected to an exterior earthing electrode system that terminates in the earth.

Terminology

Earth plane: A mesh grid made of welded reinforcing rods cast into the concrete slab or placed in a false floor with the grid made of copper conductors.

An *earthing ring bus* is the most effective form of earthing main conductor. It is typically installed in the basement or ground floor of buildings that contain telecommunications systems. The metal sheaths of cables, conduits, cabinets, and heating and water pipes are connected to the earthing main conductor using the shortest path.

The diagram below shows an earthing system with an earth plane and earthing ring bus:



Procedure

The following procedure describes how to create an earthing system for a building. The installation of an earthing system is the first step to creating an EMC environment (see *p. 489*).

Step	Action
1	Create an earth plane and a ring bus.
2	Interconnect all metal structures in the building.

Metal structures include: metal structural elements, welded concrete reinforcements, metal pipes and ducts, cable troughs, power conduits, conveyors, metal doors and window frames, and gratings. The interconnection forms a common bonding network that is the principal means for effecting earthing inside the building.

Note: Design and create a fine-meshed earth plane in areas where sensitive hardware, such as data processing and measuring equipment, will be stored or used.

Local Equipotential Bonding of Equipment and Machines

Introduction

After creating an equipotential bond for the building (see *p. 96*), you can create local low frequency (LF) and high frequency (HF) equipotential bonding of equipment and machines.

Step	Action	Considerations
1	Systematically interconnect all the metal structures of single equipment items to create local earthing systems (earth frames).	Everything from cabinets and the earth plane plate beneath them to cable troughs, pipes, and metal frames of the machines must be interconnected.
2	If necessary, add earth conductors for interconnections between exposed conductive parts.	Make sure that the used and unused ends of any cable conductor are connected to the earthing system.
3	Connect the local frame earthing system to the earthing system of the site by providing the maximum number of distributed connections.	-

Connecting Cabinets to a Local Earthing System

Make sure that there is an earth plane plate at the bottom of every cabinet.

All the exposed metal parts of components and units fitted in a cabinet must be bolted directly onto the earth plane plate to provide high-quality, durable metal-to-metal contact.

Note: Because of its excessive length, the main green/yellow earth conductor cannot generally provide HF quality earthing.

EMC-compatible Ethernet Wiring and Cable Runs

Classification of Signals

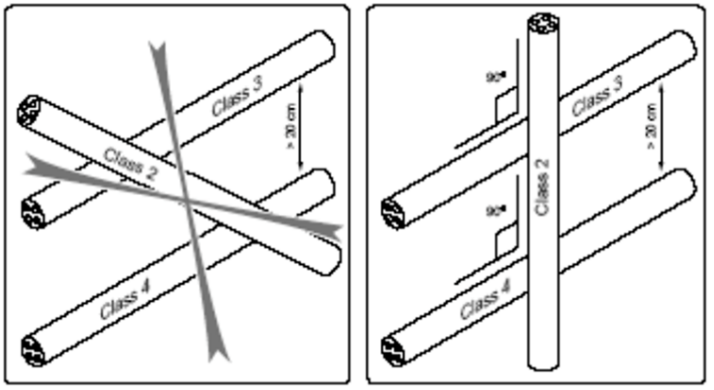
In an industrial environment, signals are classified into four categories according to their EMC performance. This classification is required to apply the cabling rules.

	EMC Performance		
Class	**Sensitivity**	**Interference**	**Circuit or Device Example**
-	PLCs	Transformers in the cabinet	-
	PCBs	Contactors	
	Regulators	circuit-breakers	
	Cables connected to inputs and outputs	Fuses	
		Switching power supplies	
	Class 1 or 2 cables carrying analog signals	Frequency converters	
		Variable speed drives	
		DC power supplies	
		Microprocessor clocks	
		Cables connected to such components	
		Power supply lines	
		Power cables	
1: Sensitive	Signal is very sensitive	-	Low-level circuits with analog outputs)
			Sensors
			Measuring circuits (probes, sensors, etc.)
2: Sightly Sensitive	Signal is sensitive. Can disturb class 1 cables	-	Control circuits connected to resistive loads
			Low-level digital circuits)
			Low-level circuits with all-or-nothing outputs
			Low-level d.c. power supplies
3: Slightly Interfering	-	Signal disturbs class 1 and 2 cables	Control circuits with inductive loads and suitable protection
			Clean AC power supplies
			Main power supplies connected to power devices
4: Interfering	-	Signal disturbs other class signals	Welding machines
			Power circuits
			Electronic speed controllers
			Switching power supplies

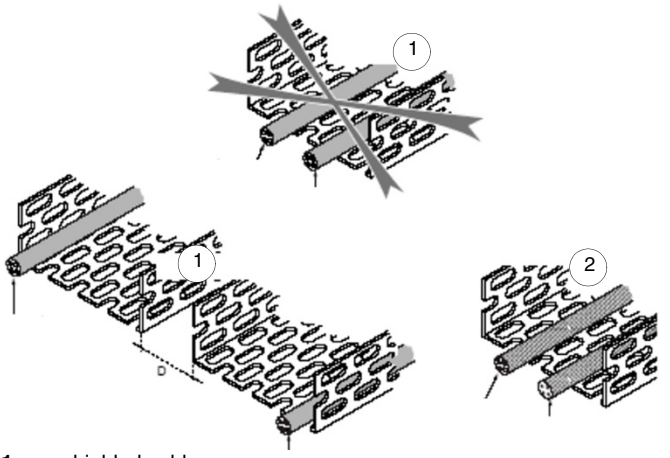
Data transmission, such as that on an Ethernet network, is a class 2 signal.

General Wiring Recommendations

- Equipotentially bond the site and the cabinets.
- Position possible sources of interference away from sensitive equipment.
- Do not combine Ethernet signals with class 3 or 4 signals in the same cable or conductor bundle.
- Always try to maximize the distance between the Ethernet cable and cables carrying signals of different classes, especially interfering signals (3-4). The longer the cable run, the greater the clearance required between cables.
- To take advantage of the HF protection effects, flatten any connection against equipotentially exposed conducting structures. For internal connections to cabinets and machines, systematically flatten the cables against the metal supports.
- Make sure Ethernet cables cross any cables carrying interfering signals (3-4) at a right angle as shown in the diagram below:



- If you need to collocate cables carrying signals of different classes in a single cable trough, use shielded cables as shown in the diagram below:

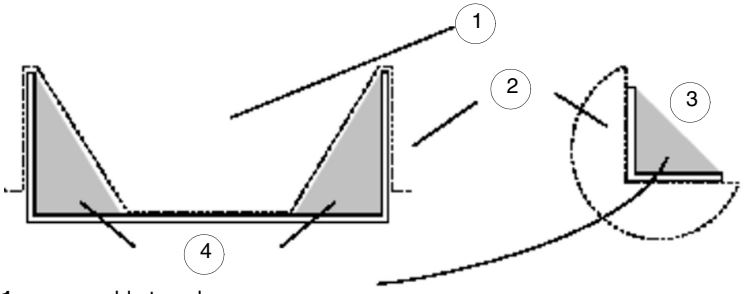


1 unshielded cables
2 shielded cables

- Establish continuity of the earth plane between two cabinets, machines, or pieces of equipment. Place all conductors against the earth plane end to end (panel at bottom of cabinet, exposed conductive parts of metal enclosures, equipotential structures of machine or building, accompanying conductors, cable troughs, etc.).
- Follow the shielding rules described in this chapter.

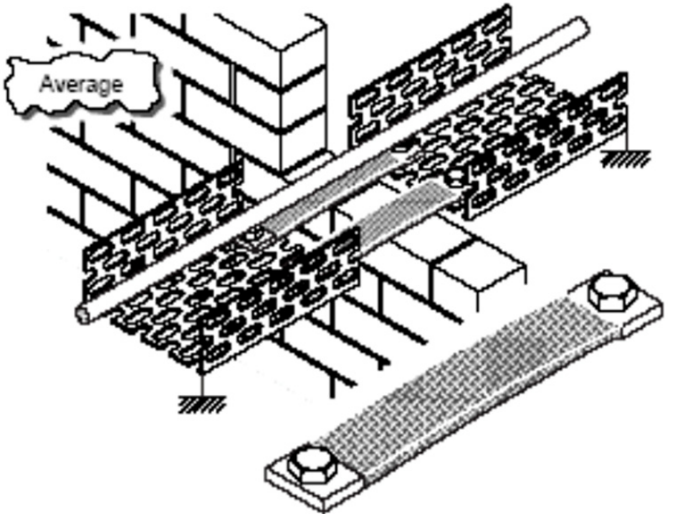
Cable Run Recommendations

- Use metal cable troughs. Correctly connected, they provide very effective cable shielding.
- The shielding, protective, or screening effects of a metal cable trough depend on the position of the cable. Install Ethernet cables in the corners of a cable duct as shown in the diagram below:



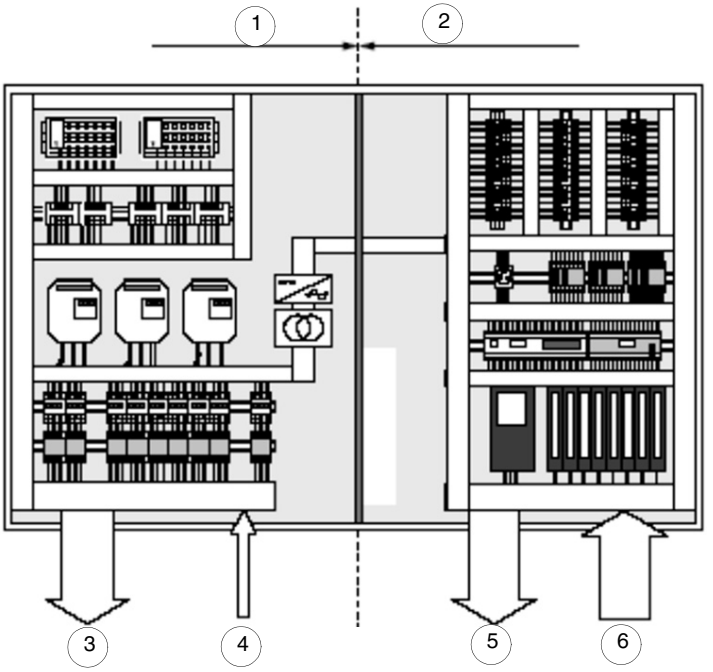
1 open cable trough
2 area exposed to EMI disturbances
3 corner angle
4 area specially protected against EMI disturbances

- If for special reasons Ethernet cable must be installed in the same trough as type 3 and 4 cables, leave the cable trough open. *This type of installation is not recommended.*
- Whenever possible, use two metal ducts, one for interfering signals (power, relays and varistors) and the other for signal cables (sensors, data, telecoms.). These two ducts can be in contact if they are shorter than 30 m. From 30 to 100 m, space them 10 cm apart, either side-by-side or one above the other.
- At all times, overlap and bolt the ends of the metal cable troughs together. If this is not possible, install a wide braided strap joining the two troughs under every table as shown in the diagram below:



Recommendations for Cable Routing inside a Cabinet

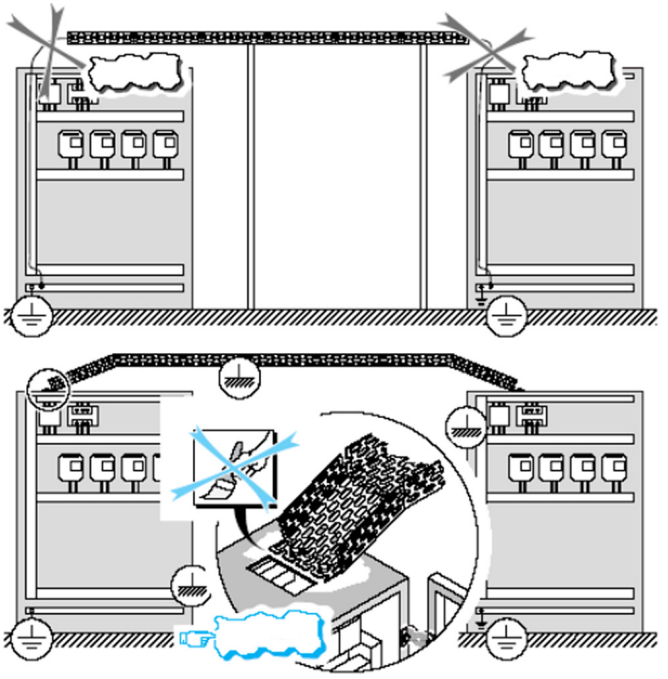
- Follow good wiring guidelines.
- Follow the cable run recommendations in this chapter.
- Always try to separate and segregate interfering and sensitive components and cables in different cabinets.
- In small cabinets, partitioning signal types by sheet metal panels bolted to the chassis may be sufficient. In large cabinets, allocate one cabinet for every class of components. When possible, lay the cables in metal ducts.



1 power
2 low level
3 to power components
4 mains
5 actuators
6 sensors

Cable Routing outside and between Cabinets

- Use metal for all ducts that are longer than 3 m.
- Bolt the ends of metal cable troughs and conduits onto metal cabinets to make satisfactory connections, as shown in the diagram below:



Cable Routing Outside and Between Buildings

There is usually a lack of equipotential bonding between two buildings. The two ground connections (one at each building) should be connected. All cable runs between two buildings must be doubled up with a large section of equipotential line (35 mm ^{2}). Use optical fiber cable for data links between buildings in any Transparent Ready application. A fiber link eliminates loop problems between buildings.

Ethernet Copper Cable Types

Ethernet Cables

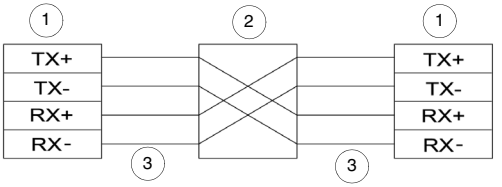
You can make two types of Ethernet cable: straight cable or crossover cable.

Straight Cable

Ethernet infrastructure devices, such as switches and hubs, are always located between two end devices. Typically these infrastructure devices *cross* the signal, and therefore the cable between the end device and the hub or switch must be a straight cable.

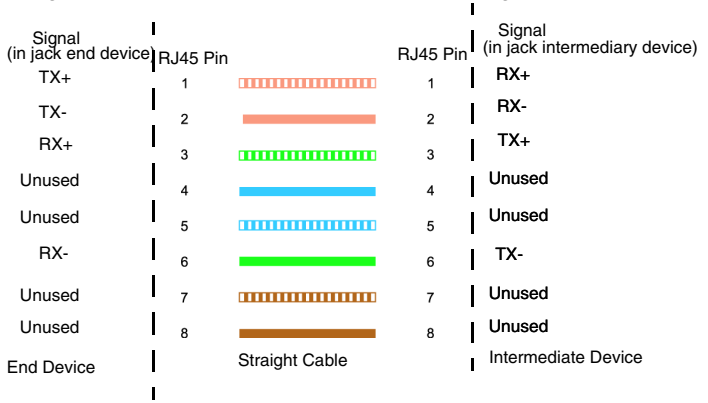
Straight Cable Pinout

The EIA/TIA 568B and IEEE 802.3u standards define the pinout for an Ethernet straight cable as shown in the diagram below:



1 end device
2 intermediary device
3 straight cable

The RJ45 pinout connection from an end device to an intermediary device uses straight cables that follow the color-code and signal specifications (see *p. 80*).

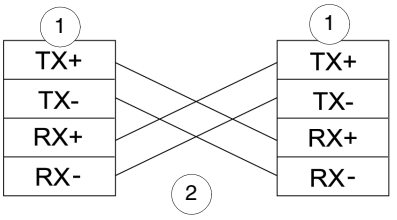


1 orange striped
2 orange
3 green striped
4 blue
5 blue striped
6 green
7 brown striped
8 brown

Crossover Cable

When two end devices on an Ethernet network communicate with each other over a direct connection, the transmit signals of one device must connect with the receive signals of the other and vice versa.

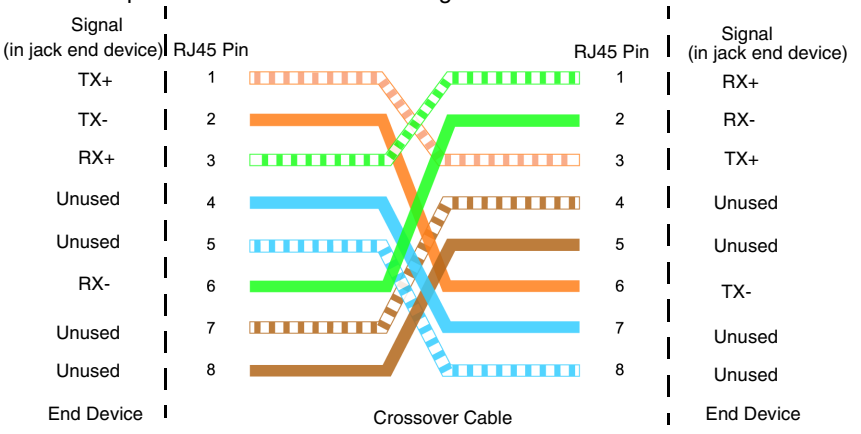
Use a crossover cable whenever you make a direct connection between two end devices. A direct connection has no intermediary device between the two end devices you are connecting.



1 end device
2 crossover cable

Crossover Cable Pinout

The EIA/TIA 568B standard defines the pinout for an Ethernet crossover cable. A direct pinout connection between two end devices uses a crossover cable that follows the specifications shown in the diagram below.



1 orange striped
2 orange
3 green striped
4 blue
5 blue striped
6 green
7 brown striped
8 brown

MDI/MDI-X

Today most of the infrastructure devices offered on the market (hubs, switches, routers, etc.) support the medium independent interface (MDI/MDI-X) functionality in their Ethernet ports. This functionality allows the auto-switching of transmit and receive wire pairs. To connect this type of infrastructure device, use either straight or crossover cable; the device senses and accommodates the TX/RX pairs.

Ethernet Copper Cable Tools

Introduction

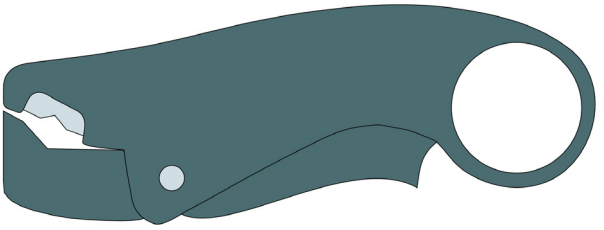
You need the following three tools to make an Ethernet copper cable:

- cable stripper
- cable cutter
- cable crimper

For instructions on how to use these tools when making cables, see *p. 109*.

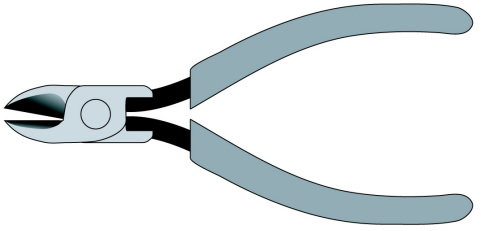
Cable Stripper

A cable stripping tool strips away the outer protective wrapping from the cable and uncovers the core conductive material.



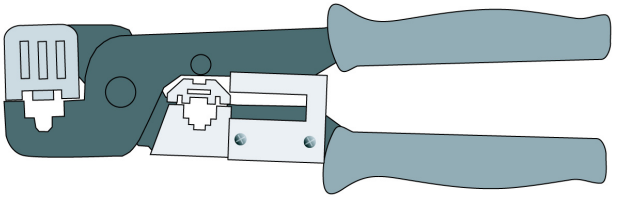
Cable Cutter

A cable cutting tool cleanly cuts through the diameter of a length of cable, separating it into two lengths. When selecting a cable cutter, choose a tool that is appropriately sized for the diameter of the cable you want to cut.



Cable Crimper

A crimper tool is used to secure the jack to the cable end by the use of pressure.



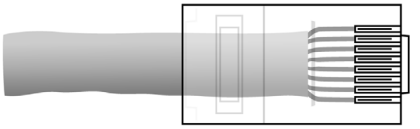
How to Make an Ethernet Cable

Before You Start

Make sure you have the following equipment available:

- RJ45 connectors (two for each cable plus extras)
- Ethernet cable
  For 10Base-T, STP Ethernet cable CAT 3 or CAT 5, 5e, or 6 are recommended; 100 m or less
- For 100Base-TX, STP Ethernet cable CAT 5, 5e, or 6 are recommended; 100 m or less
- basic cable-making tools (see *p. 108*)

Making an Ethernet Copper Cable

Step	Action	Comment
1	With the stripper tool, strip 2 inches of the plastic jacket at one end of the cable.	-
2	Hold the base of the plastic jacket with one hand and spread the wires apart with the other hand. Do not allow the wires to become untwisted inside the jacket.	Keep colored pairs of wire together and in the same order: brown, blue, green, and orange.
3	Hold the wires tightly at the point where they enter the plastic jacket. Line up your cutter across the separated wires about 0.5 in from the edge of the plastic jacket.	Make sure your cutters are aligned straight across the wires to ensure that all the wires will be cut at the same 0.5 in length.
4	Make a clean cut across the four wire pairs.	Maintain a firm grasp on the jacket as you do this. Do not allow the wires to untwist inside the jacket as you cut.
5	Grasp the RJ45 jack firmly between two fingers and slide the wires into the jack. Be sure to follow the pinout color code specifications for the type of cable you are making.	If the wires resist your efforts, keep working them forward until you have them fitted into the jack where you want them. Do not release the wires while you are fitting them.
6	Work the wires forward until they almost touch the front of the jack.	The plastic jacket should be positioned about 3/8 in inside the jack.
7	Insert the jack into the crimper and firmly squeeze the crimper until the jack is securely crimped to the cable end.	If you do not get a good crimp the first time, reposition the crimper and try again.
8	Inspect the jack to make sure you have a secure crimp. 	Look at the front end of the jack to make sure the copper connections are not pressing down into the wires. Look at the back of the jack to make sure the plastic jacket extends into the jack about 3/8 in. Note: It is very important to make sure no wires extend out of the back of the jack.

Making an Ethernet Fiber Cable

Making an Ethernet fiber cable requires special procedures and tools. Consult a trained and certified technician for assistance.

Cabling Administration

Introduction

The EN 50174-1 standard describes the specification for cabling administration. Cabling administration includes the management of:

- identification codes and methods
- cable and component labeling
- label application and location
- durability and quality of labels
- inspection and label updating

Currently, there is no international standard for these areas of cabling.

Standard EN 50174-1 and Identifiers

For general guidelines about cable labeling and identifiers, refer to chapter 7.2 and 7.5 of the EN 50174-1:2000 standard. A summary of those guidelines is included here.

The components of a cabling system are typically maintained by more than one person and, therefore, require the use of identifiers to indicate relevant information about the component. For example, you should place an identifier, in the form of a label or code, indicating where a shielded twisted pair CAT 5E cable is installed in the horizontal cabling system in a building. Chapter 7.5 of the EN 50174 standard specifies which cabling components require such identification.

Labeling Cables and Components

Labeling cables and components is a required practice in installation. Either attach labels to the component or affix them as part of the component itself. In some cases, certain components are labeled more than once. A general rule is to label a cable at both ends as the minimum requirement.

The following requirements are specified in the EN 50174-1 standard:

- Labels need to be:
  - easy to access.
  - easy to read.
  - easy to change or modify (if required).
- Labels need to be robust and their markings readable for the lifetime of the cabling.
- Labels should not be affected by dampness or become smudged when handled.
- Labels intended for outdoor use or use in harsh environments need to be designed to withstand the rigorous conditions of such environments.
- When you make changes to a cabling system, for example at a patch panel, inspect the labels to determine if the information is correct or requires updating.

Cabling Documentation

Introduction

The ISO/IEC 14763-1 and EN 50174-1 standards describe the specifications for documentation of cabling. This section summarizes the guidelines and requirements specified in standard EN 50174-1:2000, chapter 6.1 and provides recommendations for managing documentation.

Creating Documentation

When installing cabling, you need to create documentation both during and following the installation. This documentation needs to provide sufficient detail about the installation specifications. The recommendations presented here can help you determine the level of documentation that is appropriate for your installation.

Note: You should maintain the same level of documentation detail throughout the design and installation phases.

Recommendation 1: Commercial Installations

Commercial documentation should include any technical and contractual information that relates to end-user requirements and the installation undertaken.

It should also include the following:

Installation specification	See standard EN 50174-1:200, chapter 5.2
Quality plan	See standard EN 50174-1:200, chapter 5.3
Final cabling documentation	See standard EN 50174-1:200, chapter 6.2

Recommendation 2: Component Acceptance Testing

When appropriate, the documentation you supply should include detailed information about component acceptance testing. Such documentation includes:

- evidence of conformance (for example: for cables, connectors, and cable assemblies)
- cable acceptance test records and other information
- cable assembly acceptance test records and related information
- delivery information (for example: unique product identifiers of cables and components, such as dates of receipt and batch numbers, or identifier codes

Recommendation 3: Cabling Identifiers

Before you begin, choose a labeling scheme. To match cable test results to corresponding components, make sure that the name on the cable test matches the printed label on the patch panel or outlet. For best results, follow the guidelines for labeling described in Labeling Cables and Components (see *p. 111*).

Recommendation 4: Test Results Management

It is important that you carefully organize and store your test data. Proper management of test results is key to determining whether an installation is successful. Test results validate the performance and EMC compliance of a cabling system, allowing assessment of specific components, and providing valuable historic data. Performing accurate cabling tests is the only way to verify that your installation meets your original design requirements, and conforms to regional and international standards. Depending on the type of installation, you may be required to include test data in your installation documentation (see *p. 112*).

2.6 Verification of a Transparent Ready Industrial Ethernet

At a Glance

Overview

This section focuses on the process of verifying your cable installation based on the requirements of the ISO/IEC 11801 standard. Verification is a critical step in making your installation conform to all applicable standards. You should test the complete cable installation as well as the individual components of the network. You can choose to test each section of the network as it is installed (recommended) and/or plan a final verification stage when you can test everything. Because testing is the only way to verify that your installation conforms to local and international standards, Schneider Electric recommends that you become familiar with the recommendations in this section.

At this time, there is no international standard for planning and installing an industrial Ethernet network. However, there are recommendations from industrial Ethernet organizations and on-going activities that have resulted in the creation of a draft for such a standard. Plans are to publish this standard as ISO/IEC 24702 by the end of 2006.

What's in this Section?

This section contains the following topics:

Topic	Page
Transparent Ready Industrial Ethernet Verification Recommendations	115
Permanent Links	116
Channels	118
Testing a Copper Installation	120

Transparent Ready Industrial Ethernet Verification Recommendations

Introduction

Schneider Electric recommends that you follow the requirements for industrial Ethernet networks described previously in this chapter.

A certified Transparent Ready industrial Ethernet network must comply with the following requirements:.

Transparent Ready Industrial Ethernet Requirements	
(1) - Installation Requirements	Correct installation as set forth by ISO/IEC 11801.Correct installation as instructed in this guide. Correct installation as required by the application, for example, wiring of a device or machine according to the specifications supplied by the manufacturer.
(2) - Performance Requirements	Performance criteria as set forth by ISO/IEC 11801.
(3) - Environmental Requirements	Environmental protection as described in this guide.

The following discussion provides information about how to test a network and verify its conformance with requirements for items (1) and (2) in the table above.

Additional Recommendations

In addition to the requirements presented in the ISO/IEC 11801, Schneider Electric recommends that you:

1. Select the right components as defined in this guide so that the network conforms to the performance and environmental requirements of a properly installed industrial Ethernet. Read this guide carefully before you select components or begin to install your Transparent Ready industrial Ethernet network.
2. Use approved tools to measure and verify the quality of your installation and its conformance to regulations.
3. Use local and/or internationally certified installers of Ethernet networks.

Permanent Links

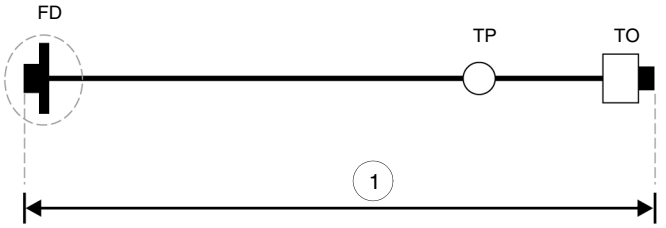
Summary

A permanent link, used for testing, is a horizontal cable with an outlet for a workstation, a patch panel and 2 m of extra cable at each end for testing. It can be a maximum of 90 m in length, in accordance with standard 568B of TIA/EIA. It consists of only the passive sections of a cable and the connecting hardware. A transition point, where cables can be connected, may be included in the horizontal subsystem of a link.

The permanent link goes from the RJ45 jack connector on one end of a cable to the RJ45 jack on the other. When a tester is connected to the cable, the effect of the tester cable and the other tester equipment connected to the cable is automatically removed from the measurement by the tester. The same removed measurement occurs with the cable between the last RJ45 jack and the remote indicator required by the tester.

Example 1

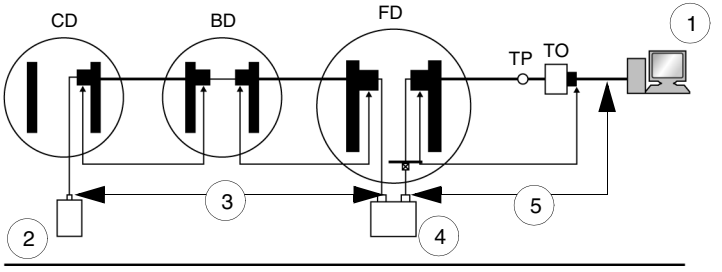
A permanent link between a floor distributor (FD) and terminal outlet (TO) is shown below. A transition point (TP) is included in the horizontal subsystem:



1 permanent link

Example 2

Below is an example of terminal equipment in a work area connected to a host server using three permanent links, two optical fiber links and a balanced cable link:



1 terminal equipment
2 host
3 optical fiber cable
4 optional opto-electronic converter
5 balanced cable channel

The optical fiber and balanced cable links are connected together using an optical fiber to balanced cable converter, a cross-connect, and two equipment cables. There are interfaces to the cabling at each end of the permanent link. Interfaces to the cabling are specified at the terminal outlet and at any point where application-specific equipment is connected to the cabling. The work area and equipment cables are not included in the permanent link.

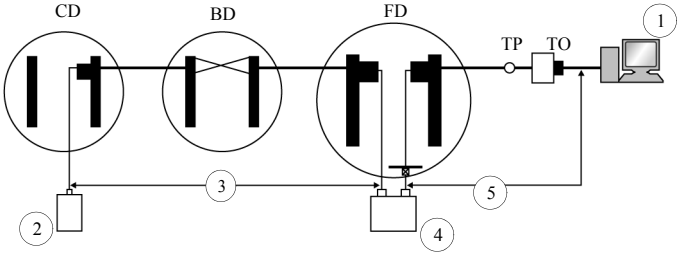
Channels

Introduction

A channel is a collection of permanent links formed by passive sections of cable, connecting hardware, work area cords, equipment cords, and patch cords. Channels do not cross switches or hubs, which are considered end points in any channel. You should test all permanent links individually and then test the channels.

Example 1

The diagram below shows an example of terminal equipment in a work area connected to a host server using two channels, an optical fiber channel and a balanced cabling channel:

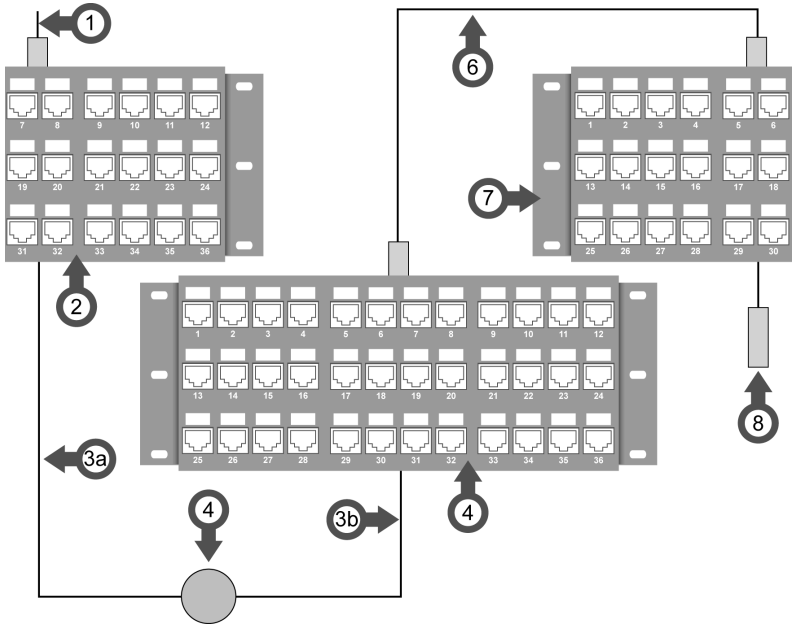


1 terminal equipment
2 host
3 optical fiber cable
4 optional opto-electronic converter
5 balanced cable channel

The optical fiber and balanced cabling channels are connected together using an optical fiber-to-balanced cable converter. There are four channel interfaces, one at each end of the copper channel and one at each end of the optical fiber channel. Equipment connections are not considered to be part of the channel. All work area cords, equipment cables, and patch cords are included in the channel.

Example 2

The diagram below shows a cable channel that connects a workstation to telecommunications closets (TC). Channels, unlike links, include the connecting hardware, equipment cords, work area cords, and patch cords. The cable channel runs from the patch cord (1) at the workstation to the patch cord (8) inside an extended closet. It connects the work area to the closets over a horizontal subsystem that includes two cables and a transition point (TP).



1 patch cord
2 patch panel
3a horizontal cable
3b horizontal cable
4 transition point
5 patch panel
6 patch cord
7 patch panel
8 patch cord
3a = 3b = 90 m max
1 + 6 + 8 = 10 max

Testing a Copper Installation

Introduction

You must test a copper installation for correct installation and performance conformance as defined by the ISO/IEC 11801 standard. For testing the installation and performance of permanent links and channels, Schneider Electric recommends that you use market-available tools and testers. Some of these tools are described below. Schneider Electric recommends the use of appropriate tools to certify copper cabling installations and performance.

Example Testers

The OMNIscanner 2 and the DSP-4000 are examples of standard tools. Both are used to test, certify, and document high-speed copper and fiber networks. They are available from Fluke Networks.

Comparison of Testers

The following table compares the features of the two testers. The testers have complementary functionality. To measure and record the specification parameters required by the ISO/IEC 11801 standard, you must use both tools.

	DSP-4300	**OMNIScanner 1**
Schematic diagnostics display	x	-
Shows crosstalk vs length	x	-
Shows NEXT vs length	-	x
Shows NEXT phase information	-	x
Shows impedance vs. length	X	-
Shows return loss vs length	-	x
Includes pass/fail S-bands	x	-
Time domain plots can be saved	x	-
Magnitude and phase information can be exported	-	x

2.7 Additional Considerations for Designing a Transparent Ready Industrial Ethernet Network

At a Glance

Overview

This section discusses some important additional topics to consider when incorporating Transparent Ready capabilities into your network design.

What's in this Section?

This section contains the following topics:

Topic	Page
Internet and IP Technologies in an Automation Environment	122
Open System Interconnection Model	124
The TCP/IP Model	125
Transparent Ready Model	127
IP Addresses and Classes	130
Multicasting Considerations	135
Multicast Filtering	136
Network Management	137
Routing	139
Introduction to Remote Access	141
Remote Access Types	142
Network Access Methods	144
PLC Connected to the Internet	147
Security Issues	149

Internet and IP Technologies in an Automation Environment

Network Design Considerations

Transparent Ready provides a wide range of devices and strategies with which you can develop a network infrastructure that supports your plant's communications. The openness and flexibility of a Transparent Ready Ethernet network require that you make some decisions about your system as you design it. These decisions include:

- how the network will be used
- what communication services it needs to support
- what paths the network will take
- response time/throughput requirements
- redundancy and resilience requirements

Why Use Ethernet

The challenge in today's world is agility, not only in the technology itself but in your willingness to adopt and refine collaborative approaches for sharing data in real time. Your communications network should be *open* to support emerging services, physical connections, and components. Because Ethernet TCP/IP is so widely embraced in the commercial world, its technologies are evolving much faster than proprietary networks, leading to more alternative solutions and more affordable components.

A standards-based Ethernet solution lets you move away from expensive proprietary systems while you maintain the security, performance, and availability required to support critical applications. With proper planning and design, you can improve processes, reduce expenses, and improve productivity.

Open Standards Support

In both the commercial and the automation domains, Ethernet TCP/IP supports all types of communication including:

- Internet Web pages
- file transfer
- industrial messages
- other standards-based services

For every communication task you need to perform, there is an existing service, standard, and managing organization. Each of these services need to be run over the most suitable network layer.

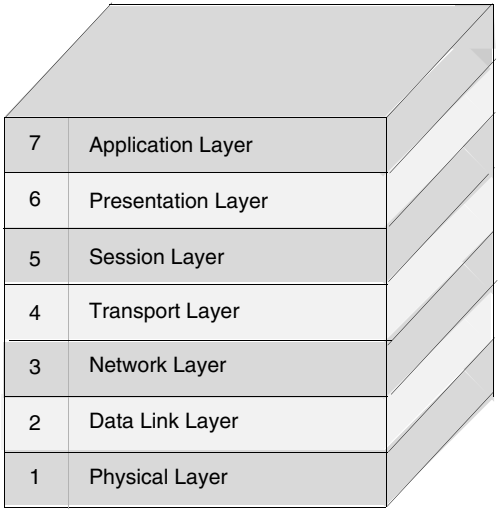
The following list indicates some of the physical media and protocols supported by open TCP/IP standards and the benefits they bring to industrial automation environments:

- twisted pair copper cables for simplicity and low cost
- optical fiber for immunity to interference over long distances
- the IP protocol for the communication redundancy inherent in it
- radio and satellite to overcome wiring restrictions
- telephone or Internet for remote point-to-point access at costs comparable to local calls
- infrastructure components with low-cost that are industrially hardened

Open System Interconnection Model

OSI Model

The OSI model defines a seven-layer model for data communications:



Layers 1 ... 6 each provide a set of functions to the layer above it, and layers 7 ... 2 each rely on functions provided by the layer below it. Messages can pass vertically through the stack from layer to layer. Logically each layer can communicate directly with a peer layer on other nodes.

The following paragraphs focus on the layers and functions of the OSI model that apply to automation systems. For a complete OSI description, refer to OSI 7498.

OSI and Automation

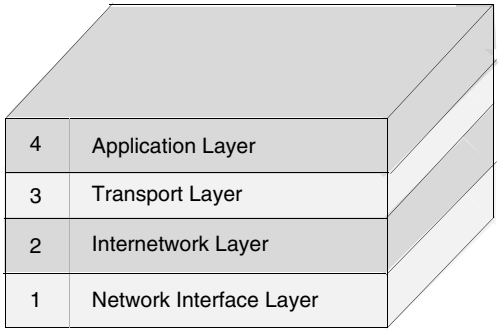
When the OSI model is applied to an automation environment, standards are applied at each layer. Each layer can perform its function (for example, the Modbus application layer transfers data around the plant) without knowing anything about the layers below it. You may adopt any suitable standard for each layer; for example, wireless or wired at the lower layers and FTP for file transfer or Modbus for data transfer at the higher layers. All this can be put in place without modifications to any other layer.

Ethernet is a standard physical and data transport system common to all automation vendors. Application protocols can vary to suit the environment; some are standard, others are specific. For example, FTP and HTTP are standard and common to all vendors, while Modbus and others are vendor-specific. Some protocols (Modbus, for instance) are open standards; others are available from only a single vendor.

The TCP/IP Model

Summary

The TCP/IP model was developed at the same time as the OSI model (see *p. 124*) and has become the protocol of choice for most data communication networks. TCP/IP consists of a four-layer protocol stack that is a compressed version of the OSI model.



This protocol stack has no specific mapping to layers 5 and 6 of the OSI model.

Application Layer

The application layer runs the actual application and protocol. Common applications include Modbus, Ethernet IP, Profinet, Telnet, FTP, SMTP and Gopher. Interfaces between the application and transport layers are defined by port numbers and sockets. TCP/IP can run different application layers simultaneously, allowing an automation network to carry SCADA (see *p. 274*) traffic, video, data, programming data and Web pages at the same time on the same network.

Transport Layer

The transport layer provides end-to-end data transfer. It is responsible for reliable information exchange. There are different transport layer protocols, the main one being TCP. UDP is another protocol that may run in the transport layer; it is used for applications that require a fast transport mechanism. Unlike TCP, UDP does not have the ability to divide long messages and reassemble their packets in the correct order on the other side, and it is unable to send retries. The application that is sending the message is required to make sure that the messages are sent in their entirety or, if required, retransmit the message.

Internetwork Layer

The internetwork layer separates the physical network from the layers above. IP is the most important protocol in this layer. IP is a data-oriented protocol used by source and destination hosts for communicating data across a packet-switched internetwork. IP is a connectionless protocol that does not assume reliability from the lower layers. It is sometimes referred to as the *Internet layer* or *network layer*.

IP does not provide flow control or error recovery. These functions need to be provided at either the transport layer (if you use TCP) or the application layer (if you use UDP).

The message unit in an IP network is called an IP datagram or packet. An IP datagram is transmitted across TCP/IP networks. IP provides routing functions for distributing datagrams to the correct recipient for the protocol stack.

Other internetwork protocols include ICMP, IGMP, ARP and RARP. These protocols do not replace IP, but they can work alongside it.

Network Interface Layer

The network interface layer is the interface to the actual hardware. It is sometimes referred to as the *link layer* or the *data link layer*. It supports packet-oriented or stream-oriented interfaces and does not guarantee reliable delivery.

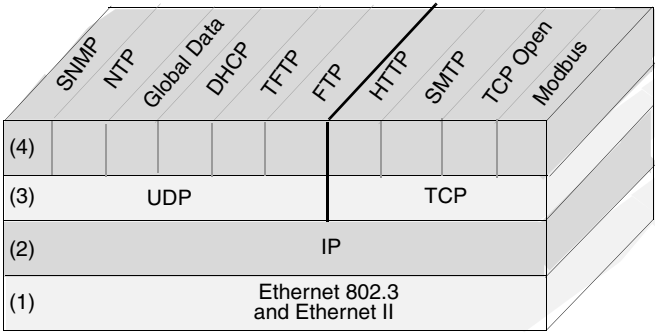
TCP/IP does not specify any particular protocol for this layer. It can use almost any network interface, making it a flexible network with backward compatibility for a legacy infrastructure. IEEE 802.3, ATM, and FDDI are examples of network interface protocols supported by TCP/IP.

The ability to run the application layer and TCP/IP over different physical layers allows the data (SCADA traffic, for example) to run across a fiber link to remote sites and then across a star-based copper link to the PLC or even a satellite link. All this can be done without changing the application layer or the TCP and IP layers for addressing and data delivery.

Transparent Ready Model

Summary

The following diagram shows how Transparent Ready implements the four-layer TCP/IP model (see *p. 125*):



1 the internetwork layer is Ethernet 802.3 and Ethernet II
2 the network interface layer is implemented with IP
3 the transport layer comprises UDP and TCP
4 the application layer comprises 10 Transparent Ready services

Ethernet II and IEEE 802.3

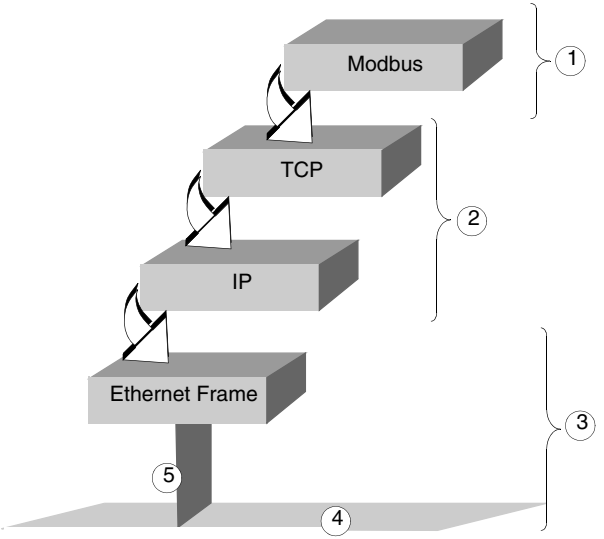
Ethernet II is the product of a joint development effort by Xerox, Intel and Digital. It was introduced to the market in 1982. A year later, the IEEE released their 802.3 specification. Functionally, they are very similar, but the way in which the two formats frame one of the data fields make them incompatible with one another.

Ethernet II and IEEE 802.3 refer only to the physical characteristics of the network:

- the way in which information accesses the network (CSMA/CD)
- how the network frames the data messages
- the physical characteristics of the network itself (its topology, cable requirements, connectors, infrastructure, and so on)

IEEE 802.3 and Ethernet II can coexist on the same physical cable and use the same signals. The only difference between the two is the data format.

A data frame can be pictured as a block in which information travels along the network wire:



1 application protocols
2 internet protocols
3 Ethernet II or IEEE 802.3
4 Ethernet topology
5 access to network (CSMA/CD)

The Internet Suite of Protocols

Industrial automation professionals initially viewed Ethernet as a nondeterministic approach to a set of applications that depended heavily on real-time solutions. Most suppliers preferred to focus on other technologies, mostly proprietary. What finally brought Ethernet acceptance in the industrial world is a combination of features called the Internet suite of protocols.

This suite, known as TCP/IP, was introduced to the market in 1983 as a reliable and simple way to communicate from multiple sites with different network types. TCP/IP is independent of the underlying network technology. It can run on top of Ethernet, IEEE 802.3, token ring, PPP, ATM, DSL or several other technologies.

The suite comprises many protocols, the best known of which are TCP and IP. Other parts of the suite include:

- the ARP and RARP data link layer protocols
- transport protocols such as UDP
- management and information protocols such as SNMP, DNS, BootP and NTP
- routing protocols such as EGP
- application protocols such as FTP, TFTP, Telnet, SMTP and NFS

These protocols each provide different functions and are located on different layers in the model.

Model Support for Transparent Ready Services

The Transparent Ready model supports universal Ethernet services such as HTTP, BootP/DHCP, and FTP. The model also supports these Transparent Ready-specific services:

- Modbus TCP messaging
- I/O scanning
- faulty device replacement (FDR)
- SNMP network administration
- global data
- bandwidth management
- NTP time synchronization
- notification of SMTP events via electronic mail
- optional TCP open

At the transport layer, UDP supports six services and TCP supports four services:

Transport Layer	Application Layer	Service Provided
UDP	SNMP/MIB	Network management
	NTP	Time synchronization
	RTPS	Global data transfer
	DHCP	Faulty device replacement (FDR)
	TFTP	
TCP	FTP	
	HTTP	Web server
	SMTP	Email notification
	TCP Open	
	Modbus	Message handling
		Modbus I/O scanning

IP Addresses and Classes

Summary

An IP address allows a device to have a unique logical address to locate the device on the TCP/IP network and group it with others for network design and management purposes.

Dotted Decimal Notation

A computer sees an IP address in a binary form of 32 bits. For ease of use, the 32 bits have been divided into four 8-bit groups. Each group is converted into its decimal equivalent, which results in four decimal numbers separated by dots. As an example, an IP address in binary 10001011.00101101.00100100.00001100 can be written in a simpler format by converting each individual octet into a decimal value,139.45.36.12.

10001011	00101101	00100100	00001100
139	45	36	12

Network Address Defined

An IP address consists of two parts, the network address and the host or device address. The subnet mask is a filter that is applied to the IP address to determine which part of the IP address is the network address and which part is the host or device address. The network address is the part of an IP address that identifies the subnet that the address is a part of. The mask is a 32-bit value that uses one-bits for the network and subnet portions and zero-bits for the host portion. In classful addressing, the network address portion of the IP address consists of one, two or three octets, starting from the left.

IP Address	11000000	10100000	00010100	00110000	192.160.20.48
Subnet Mask	11111111	11111111	11111111	00000000	255.255.255.0
Network Portion of IP Address	11000000	10100000	00010100	00000000	192.160.20.0

Classful Addressing

In classful addressing, these are the possible classes of IP addresses to use, depending on the size of your enterprise:

- Class A = 0.0.0.0/8 through 127.0.0.0/8
- Class B = 128.0.0.0/16 through 191.255.0.0/16
- Class C = 192.0.0.0/24 through 223.255.255.0/24
- Class D = 224.0.0.0 through 239.255.255.255 is used for multicasting (see *p. 135*)

The remaining addresses known as Class E are reserved for experimental use.

An address comprises 2 parts:

- the network information
- the host (node or end device) information

The IP address comprises 4 sets of decimal numbers called octets, each separated by a period, with a value from 0 to 255 that represents a converted binary-to-decimal number

Classless Addressing

Classless addressing (also known as CIDR or supernetting) was developed to improve current Internet problems regarding the efficient utilization of address space. It also is used to add to the routing scalability of networks. Allocating portions of the large but limited number of addresses to an enterprise all at one time often resulted in the waste of some reserved addresses. Including each network in a table resulted in overload. Also, medium-sized enterprises that fit the class B category have multiplied the fastest, using much of the space in that class. Classless addressing, by allowing the delineation point between network information and host information to be flexible, has expanded the number of addresses available to all sizes of enterprise and has reduced the size of routing tables.

Choosing an Address Range

Public addresses, for use on the Internet, are assigned by a governing organization called the Internet Assigned Numbers Authority (IANA). However, your company may already have been assigned a section of addresses and your IT person can allocate the quantity that you need. If you have not been given a predefined set of IP ranges, you should be aware that the following three blocks have been reserved by IANA for private Internets:

10.0.0.0 - 10.255.255.255 (10/8 prefix)

172.16.0.0 - 172.31.255.255 (172.16/12 prefix)

192.168.0.0 - 192.168.255.255 (192.168/16 prefix)

Special Addresses

There are three types of special addresses that should be mentioned:

- broadcast
- loopback
- network

A broadcast message, usually used for network management and diagnostic purposes, is addressed to all stations on the network. The destination address in a broadcast message is made up of all 1s (255.255.255.255).

A loopback address is used to test the implementation of the TCP/IP protocol on a host. The lower layers are bypassed by sending to a loopback address. This allows the higher layers (IP and above) to be tested without exposing problems at the lower layers. 127.0.0.1 is the address typically used for loopback testing.

As described in the previous section, network address refers to the network portion of an IP (Internet Protocol) address.

Sufficient Addresses

In planning for your network, you should anticipate the need for these addresses:

- for the gateway (one address)
- for broadcast
- for the number of services
- for future devices added to the network

Tools can be found on the Internet to help calculate the number of addresses your network requires.

Subnetting

Forming subnets divides a large network into more manageable segments; it can allow you to expand the number of networks, while using only the single IP address. You need not apply for more of the limited number of IP address numbers.

Network traffic is reduced by sending messages to only a limited segment of the network. Subnetting can be particularly helpful on a network that handles a lot of broadcast traffic. It can also be useful if you have a slow WAN link connecting your far-flung locations.

To subnet, the default subnet mask for a network is extended to cover bits of the address that would otherwise be part of the host field. Once these bits are masked, they become part of the network field and are used to identify subnets of the larger network.

Choose a subnet of a size (number of addresses) appropriate for the number of devices on it; a size that allows for growth, but is not wasteful of addresses. For example, if you have 50 devices, choose a subnet of 64 addresses, not 1024. The following table contains one column presenting the number of addresses and another with the corresponding mask.

Subnet Mask	Number of Addresses
0.0.0.0	4,294,964,086
128.0.0.0	2,147,482,048
192.0.0.0	1,073,741,024
224.0.0.0	536,870,512
240.0.0.0	268,435,256
248.0.0.0	134,217,628
252.0.0.0	67,108,864
254.0.0.0	33,554,432
255.0.0.0	16,777,216
255.128.0.0	8,388,608
255.192.0.0	4,194,304
255.224.0.0	2,097,152
255.240.0.0	1,048,576

Subnet Mask	Number of Addresses
255.248.0.0	524,288
255.252.0.0	262,144
255.254.0.0	131,072
255.255.0.0	65,536
255.255.128.0	32,768
255.255.192.0	16,384
255.255.224.0	8,192
255.255.240.0	4,096
255.255.248.0	2,048
255.255.252.0	2048
255.255.254.0	1024
255.255.255.0	512
255.255.255.128	128
255.255.255.192	64
255.255.255.224	32
255.255.255.240	16
255.255.255.248	8
255.255.255.252	4
255.255.255.254	2
255.255.255.255	1

For a subnet with 64 addresses, the subnet mask is 255.255.255.192. The IP address would therefore be 192.168.1.1, the network address would be 192.168.0 and the host range would be from 0.1 to .63.

Using Subnets in a Plant

By using subnets in your plant, you can divide the plant into sections to avoid traffic overload. Use a router to pass traffic between subnets. There should be no more than 200 to 300 devices per network. However, it is preferable to have a smaller network with 50 to 100 devices. Add networks if you must accommodate more devices than the preferred number.

Assigning Addresses

You may obtain addresses from the governing organization or use a group of those already assigned to your company. The next step is to assign a unique address to each end device by one of several methods. In static addressing, each user is assigned one fixed IP address to be used every time the user connects to the Internet. Dynamic addressing assigns the IP automatically, as needed. BootP (Bootstrap Protocol) as its name suggests, allows a workstation to configure itself without a hard drive or floppy disk. The workstation can discover its own IP address, the IP of a server and a file to be loaded into memory to boot the machine. DHCP assigns a different address to a device when it requests one. The software, rather than the administrator as in static addressing, keeps track of the IP addresses.

Multicasting Considerations

Summary

IP multicast, a method of selectively sending messages promoted by an industry consortium of prominent companies, is an up-and-coming technology that will be used increasingly for:

- *monitoring*: manufacturing and other types of real-time information, sensor equipment or security systems.
- *announcements*: network time, multicast session schedules, random numbers, keys, configuration updates, etc.
- *file distribution and caching*: Web site content, executable binaries
- *scheduled distribution* of audio and video
- *push media*: news headlines, weather updates, sports scores, etc.

On the Internet

You should make sure that your router and/or switches support multicast, your workstations are configured to join a multicast group and that you have installed any specific applications needed to receive the multicast.

IP Multicasting Transport

The UDP protocol is used for IP multicasting. The multicast address selected is important in allowing network managers to control the way hosts (end devices) join groups and how routers exchange multicast information.

IP Multicast Addresses

In IP multicasting, each group has a multicast group ID, a set of Class D IP addresses used to specify the destination of a message. The addresses range from 224.0.0.0 to 239.255.255.255. Each multicast IP address can have a number of hosts listening to it. Hosts can belong to a multicast group, and the IP addresses are associated with that group. Each configured device has a multicast IP address that is in addition to its own IP address.

Class D addresses can be classified as follows:

- *permanently assigned*: addresses in the range 224.0.0.0 to 224.0.0.225, permanently assigned by IANA for certain applications such as routing protocols; for example:
  - 224.0.0.0 for the base address
  - 224.0.0.1 for all systems on this subnet
  - 224.0.0.2 for all routers on this subnet
  - 224.0.0.4 for DVMRP routers
- *nonpermanent*: addresses in the range 224.0.1.0 to 238.255.255.255, used for assignment as needed on the Internet
- *administered nonpermanent*: addresses in the range 239.0.0.0 to 239.255.255.255, reserved for use in private Intranets

Multicast Filtering

Summary

Two services and one variation can be used for multicast filtering:

- IGMP
- IGMP snooping
- GMRP

IGMP

IGMP is used by a router to establish multicast group membership and send a message to a particular network that has multicast members. It stops forwarding the message when the last destination on a segment receives the message. IGMP is used for the routing of multicast messages on the Internet, as well as on a LAN. IGMP operates at layer 3; it does not provide filtering at the switch level.

IGMP Snooping

This method passively snoops on the registration information of IGMP packets to learn about group membership. This information is used to compile a list of destinations to receive a given message. IGMP filters at the switch level by listening to device and router messages and the IGMP Querier. (The querier is normally the router, but if this is not the case, an IGMP Querier is required.)

GMRP

GMRP is used to dynamically configure switch ports so that IP multicast traffic is forwarded only to those ports associated with IP multicast end users (hosts). A switch can exchange information about groups with other switches, stop (or *prune*) broadcast traffic after all subscribed destinations have received the message, as well as create and manage multicast groups. GMRP operates in layer 2 with layer 2 devices such as Ethernet switches. Transparent Ready supports GMRP.

MAC Address Mapping with Class D Addresses

NICs exchange information using a unique MAC address, not an IP address. To join a multicast group, you must run an application on a host that can inform its network device driver that it wants to be a member of a specified group. The device driver maps the multicast IP address to a physical multicast address.

Obtaining Group Membership

Group memberships are dynamic. Members are able to join and leave a group anytime they want. Senders need the multicast IP address only to send information, regardless of whether or not any hosts are listening at that time. When a host wants to join a multicast group, it signals its intention to the router that sits on the same subnet.

Network Management

Summary

Managing your network allows you to monitor:

- who is on the network
- network traffic
- network traffic errors
- device errors

Network Management Components

Network management is accomplished by the use of a management system, a protocol that allows the management system to communicate with the devices, and end devices such as switches and routers that are configured to support the protocol.

SNMP Protocol

SNMP has become the standard protocol for network management. It comprises

- an agent, the software module for network management that resides in a device
- a manager (NMS) that can query and get responses from agents and set variables in them
- a managed device with a MIB

MIB

A management information base (MIB) is a data base of managed objects such as broadcast messages sent and received or corrupted packets. Each specific instance of a managed object is called a MIB variable. Most devices support MIB II with some extensions for switches.

Private MIBs

A private MIB, installed in addition to the standard MIB, is supplied by a vendor and is specific to that vendor's products. Schneider has a set of MIBs to load into a management package in order to manage devices.

Setup of a Network Management System

In order to set up a network management system, load the MIB file into the manager. The manager knows the required data and addresses needed to *discover* the devices on the network. It will feed the MIB files and begin to monitor the network.

Security

A community string, configured on a router or switch, is a password that defines a community of end users that can access SNMP information on a network device. The community string should be an alpha-numeric string of at least 8 characters. Designating access to devices in this way aids in providing security for your network.

Security in the latest SNMP version v3 controls:

- the modification of information
- masquerading
- the modification of the message stream
- the disclosure of information

SNMP version 3 provides better security features than versions 1 and 2.

Effects on the Network

When setting up a network management system, be aware of the effect that the system might have on network speed and congestion. If you program the system to monitor the network at too frequent a rate, you could overload the network with traffic. An update rate of every 30 s to 1 min should be sufficient to provide data without generating unnecessary traffic.

Routing

Summary

Routing is a method of finding paths to move messages from one network to another network. The Internet uses a process in which each node (router) looks at a packet's header information, calculates the next *hop* on the route to the destination and delivers the packet to the next node, which repeats the process. The process occurs at Layer 3.

Routers

A router is a device that connects two or more networks at a gateway and forwards packets along the network. It has an Ethernet card or another interface for each network.

Routing Process

The message is looked at by the sending device. If the destination is local, the message is sent directly to the end device. If the destination is remote (not on the same network), the message is sent to the default gateway (the local router). This router uses its own information about connected networks to pass the message, either to the final network (if it is directly connected) or to the next router closer to the final destination.

Routing Tables

A routing table contains a record of the best routes possible to reach a number of given network destinations. A routing table includes information needed for determining that route; the destination IP address, the gateway IP address and the physical interface identification. Each router knows only its local networks, but passes this information on to other routers, which builds up tables. The router may be programmed to know just the first attached network or it may know several downstream. If it does not know where to send a message, it will pass the message to its own default router, which is farther upstream in the network, for processing. Routing tables are created either by hand for a small system or automatically using routing protocols.

Routing Protocols

Routing protocols decide on the contents of routing tables. In a small stable system, it is often best to program the routing tables by hand. In a larger system or one that requires redundancy, a routing protocol needs to be chosen.

Protocols used within a system include RIP, a distance vector protocol that is the most widely used, and OSPF, a more recent link-state routing protocol.

A distance vector protocol uses distance, as measured in routing hops, to determine a packet's optimal path. Each node shares its routing table with the neighboring routers. In a link-state routing protocol, every switching node (router) receives a full map of network connections, passed from one node to another, which it uses to calculate the best next hop from it to all possible destinations on the network.

RIP is robust, its configuration is simple and its algorithm does not impose a burden on storage or computation capacity. However, it does not directly support subnetting, requires a lot of bandwidth, may be hard to debug, may have problems making the many hops on a larger network and has weak security.

OSPF, among its other advantages, supports subnetting, verifies a link by sending a small packet and can work with a larger network. It does, however, use a lot of memory and computation capacity and is rather more complex.

When considering which protocol to use, look at the ability to handle the number of routers in our system, convergence time (how long it takes to build the routing tables after a change), and the amount of traffic generated by the protocol itself.

Path Cost

Path cost, usually based on criteria such as hop count and media bandwidth, is used to compare the *cost* of passing a packet over various paths on a network. Path cost is defined for each network and is used by the routers to choose the optimal path to the final destination; the lower the cost, the better the path. This is one way to prevent the data from being sent around and around the router network.

Introduction to Remote Access

Summary

In a plant environment, access to the industrial control system is essential for capturing data, troubleshooting, control, and minor adjustments. With critical applications and industrial processes demanding 24x7 attention, the ability to administer network devices from a remote location is increasingly desirable. Remote access is useful for:

- OEMs whose machines may be installed anywhere in the world
- end users who may not maintain local support staff
- system integrators looking to add more value to their offer
- systems requiring remote data gathering

Examples

For example, an alarm for tank overflow is paged to an operator. The operator logs in, checks the status of the tank, determines that it is safe to halt pumps, and pauses the process until morning so that the situation can be investigated and corrected.

Another example is that of an OEM who ships a machine to a customer in another country. The customer chooses to use a different type of sensor than the one the specified by the OEM. After start-up, the system does not work as planned. With remote access, the OEM is able to log into the plant, modify the program, and get the customer's machine running without a costly, time-consuming on-site visit.

Methods

Three methods of remote access are commonly used, each via a different protocol:

- direct access to a PLC via dial-up
- remote control of a PC via dial-up
- remote access to the complete network

To determine the most suitable type of connection, you need to establish a list of functions that your remote connection must provide. Common features include:

- data gathering
- remote troubleshooting
- programming software
- SCADA
- remote programming
- security

For corporate private networks, several considerations are important with respect to a remote access capability:

- reliability
- performance
- scalability
- manageability
- secure connectivity through encryption and/or authentication of users and devices
- accessibility

Remote Access Types

Direct Dial-up to the Device	Direct dial-up is handled by a modem attached directly to a plant PLC or other device. An operator is able to dial into the modem and access the device port as in a local connection. The operator is restricted to serial protocol access to only a single PLC or device via Modbus.
Remote Control of a PC via Dial-up	Remote control dial-up involves taking control of one of the PCs on the site. The remote operator actually uses the PC on site. All inputs from the remote keyboard/ mouse are sent to the site PC, and the screen image of the site PC is shown on the remote PC.
Network Access	Network access involves extending the Ethernet network to a remote station. It may be implemented using either a RAS server or by VPN. The Ethernet connection allows full access to all PLCs and other devices on the site's Ethernet. The remote station can access Web pages, implement diagnostics, do programming, connect to network printers, and access documents from servers.
Connection of the PLC to the Internet	When a connection from a PLC to the Internet is established, any client connected to the Internet can access the PLC. Remote clients can access Web pages, implement diagnostics, programming and perform many other functions.

Comparison of Remote Access Options

Method	Accessible Systems	PLC Protocol Access	Web Page Access	Setup Cost	Ongoing Cost	Setup Difficulty	Client Requirements
Direct Dial-up to Device	Single PLC	Yes	No	Low	Phone charges	Low	Must run full PLC/ SCADA software etc.
Remote Control of PC via Dial-up	All devices	Yes	Yes	Low	Phone or Internet Charges	Low to high	Remote control software must be installed on local and remote PC. Note of caution: in this case, security may be compromised
Remote Access via RAS or VPN	All devices on the local Ethernet network	Yes	Yes	Medium	Phone or Internet Charges	Low to high	PLC/SCADA software Web browser
PLC Connected to the Internet	All devices have an Internet connection	Yes	Yes	Medium	ISP costs (High)	High	PLC/SCADA software Web browser

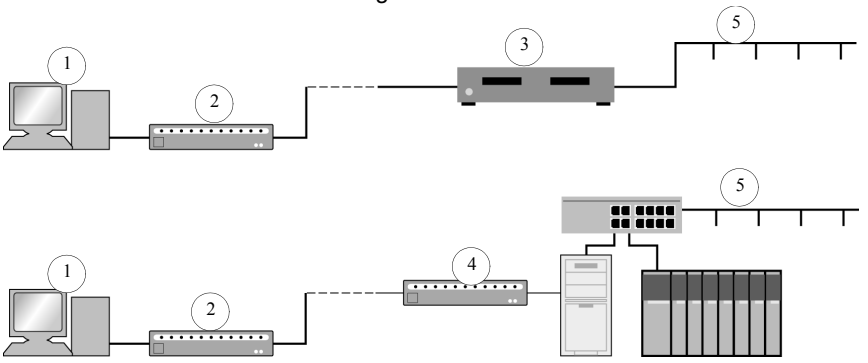
Network Access Methods

Summary

The cost and the number of users you need to support are the determining factors when choosing a remote access method. You should not deploy VPNs or any security technology without an associated policy (see *p. 149*) in place. Be aware of the data on your network that is considered sensitive so that it can be properly protected when transported over the Internet.

Remote Access Server

Two general layouts of a remote access system are shown below, one with a dedicated RAS server and one using a Windows server PC.



1 remote PC
2 modem
3 RAS server
4 modem
5 network

RAS System Advantages

- A new global IP address is not needed. The IP address of the PLC can be the one assigned on the company network.
- No ISP is needed.
- There are no ongoing service costs for the company running the PLC.
- You can deliver a configured system anywhere in the world that becomes operational when a phone line is connected. (A modem compatible with the location must be installed prior to shipping.)

RAS System Disadvantages

A direct phone connection is required between the remote client and the RAS server. Potential problems include:

- cost
- poor quality phone connection
- slow speed

RAS System Components

- A RAS server needs to be added to the Ethernet network that is connected to the PLC.
- The default gateway of the PLC is set to the IP address of the RAS server.
- A modem is added to the RAS server. A good quality locally supplied modem should be adequate.
- The RAS server should be configured for any security or firewall settings that are required.
- A modem is added to the remote client.
- The remote client is configured for dial-up access.

RAS Server Implementation

Whether your company requires a dedicated RAS server with security and firewall features or just a simple Windows NT server or workstation, consider the following security and system factors in your network design:

- *support for external modems*: Some standalone RAS servers do not support serial style modem connections.
- *security verification*: including Chap, PAP or Windows authentication. Many systems provide an additional security layer before the user can access a Windows style network. If there are no Windows servers on the network, the RAS server becomes the main verification point.
- *dial-back*: so that the RAS server and modem can be configured to dial a user back at a pre-configured phone number. This security feature requires that anyone attempting to access the system be at a specific phone number. The client dials the RAS server and enters a name and password; the RAS server hangs up and dials the user back at a fixed phone number. While this feature provides excellent security, it can also be a very limiting option. When an OEM ships a dial-back machine to a customer, the end user pays most of the cost of the RAS connections because the phone connection is initiated from the PLC end of the line.
- *allowed protocols*: Many RAS servers can be configured to allow only specific protocols, such as IP traffic. Make sure that all the protocols you require are in the list of allowed protocols.
- *firewalls*: Some RAS servers can incorporate or add a firewall. A firewall can provide a very secure environment for the PLC and prevent almost all unauthorized attempts to access the PLC or network.

Virtual Private Network

A VPN creates private networks using a transport mechanism such as the Internet or public telephone network. It routes IP through a secure tunnel created between two networks. The idea is to create what appears to be a dedicated private link on a shared network using encryption and tunneling techniques. VPN technology is a cost-effective way to provide secure connectivity to remote locations over the public Internet. Site-to-site VPNs can be used to provide connections to remote office locations. This can save on expenses associated with costly leased lines. VPNs also provide a secure means of connecting to a private network from any Internet connection.

Common VPN Environments

- *remote access VPN*: The most common and familiar situation for remote access may be that of an individual user connecting from a remote location, such as a residence or travel destination, to a private network at the user's place of employment. The most common way to accomplish this today is using a VPN. which is not only faster, but more cost effective, flexible, and convenient than leased or private lines.
- *point-to-point VPN*: VPN technology can also be used to connect remote sites or branch offices to the organization's main network. VPNs are replacing such WAN technologies (see *p. 62*) as leased lines, frame relay, and ATM. A VPN provides traditional WAN requirements for this situation, such as multi-protocol support, high availability, scalability, and security. As mentioned above, it also has advantages over private WAN services.

PLC Connected to the Internet

Summary

Permanently connecting a PLC to the Internet can be costly and difficult for a small company or OEM. However, for a large company that already has a permanent Internet connection and is familiar with such issues as hosting its own web servers, the task is simply an extension of their existing system.

Internet Connection Benefits/ Disadvantages

This system offers several benefits over the previous RAS setup:

- The PLC is permanently connected to the Internet. This allows quick access to the PLC from any PC connected to the Internet, no modem required.
- No long distance phone calls are required to access the PLC; simply connect to your local ISP.
- The number of simultaneous remote connections to the PLC is not limited by the number of modems on the RAS server.

However there are some serious disadvantages and difficulties:

- A permanent connection to the Internet is required.
- A permanent globally unique IP address is required for the PLC; this may not match the address used on your local system.
- There is no easy way to limit access to the PLC, unlike using callback for a RAS server, although firewalls can be used for access control.

General Internet System Setup

General system setup is as follows:

- A local ISP needs to be found to provide a permanent connection from the PLC to the Internet. This can be very expensive as most permanent connections use methods other than modems. If you are planning to use a modem, consult with the ISP and phone company to check that a phone connection can be left connected indefinitely.
- Obtain a permanent unique IP address for your PLC. For small companies, this address may be obtained through your ISP. Leasing this address from your ISP may be expensive as there are a limited number of these addresses worldwide and the ISP can either lease an address to a single user or share this address with many users. Larger companies should already have a series of these addresses.
- Have your ISP or IT staff configure any routers that are needed to access this IP address from the rest of the Internet. Also configure the PLC's IP address and gateway.
- A firewall (see *p. 150*) should be installed to separate the portion of the network connecting your PLC to the Internet and the rest of your network. This is done to prevent users accessing other parts of your network. A firewall can also be installed between the PLC and the Internet to restrict the type of access users have to the PLC. Presently no available firewalls permit Modbus data commands (reading/writing of data) while also preventing programming commands (programming the PLC using Concept, Proworx or Modsoft).

If you are planning to permanently connect your PLC to the Internet, Schneider Electric recommends working closely with personnel from your IT department or, if they are unavailable, partnering with a reputable local ISP.

Security Issues

Summary

There are many different aspects to network security. Network security includes allowing an operator day-to-day access to a PLC, the prevention of damaging but non-malicious activity, and the enforcement of plant procedures and authorizations. However, preventing malicious activity is much more difficult than these other areas of security. Malicious activity includes unauthorized access, interference with corporate data, virus attacks, denial of service, spoofing of Websites and email, as well as fraud and other criminal activity. Securing your network against malicious intent is very difficult to implement and requires the advice of security experts. The amount of time required to secure the network against breaches depends on the level of skill the attackers possess, but prevention requires constant monitoring. Security against non-malicious activity, however, can be implemented by personnel who do not possess this level of specialized training.

Security Policy

Your security policy defines the information and services to be accessed, how they can be accessed and who will be given access to them. Defining a security policy, rather than just beginning to implement one without a plan, is more likely to help you cover all areas. Planning also makes it easy to remember what security to apply when you add to the network.

Passwords

Passwords should be changed monthly. Do not choose simple user names and passwords if you are trying to prevent malicious access. Default passwords on all devices should be changed or disabled, since default settings are often easy to find in user manuals.

Physical Access

Preventing physical access to a network is crucial in implementing security against malicious attacks. It is very easy to get SNMP or telnet passwords when you have physical access to the network. Therefore, preventing physical access to the network infrastructure is crucial in keeping control of the network layout. The time spent organizing network traffic in an efficient way can be negated by users who make the network inoperable or prevent device communications.

Firewalls

A firewall is a device or program that filters the information coming through a connection into your network. A firewall inspects each packet and decides if that packet will be allowed to pass, based on:

- source IP address
- destination IP address
- destination TCP port number (which protocol is being used)

Place firewalls ar critical junctions within your networks, such as:

- between the office network and the plant floor
- between areas of your plant
- between contractor laptops and the plant

By filtering with basic firewalls, you can limit access to a certain area of your network or to a certain device based on the information coming from the computer attempting access. Since the access is IP based, you cannot filter per person. You can allow access to a device, but restrict the protocols that can be used. For example, you can allow web page viewing, but not FTP for firmware transfer.

Modbus Filtering and Firewalls

With Modbus filtering, however, you cannot allow data monitoring without allowing programming as well, since these are both in one protocol. One possible solution is to allow only several OPC services to perform data access and to block all other devices. This also prevents monitoring with a programming package.

Advanced Firewalls

More advanced firewalls are appearing that can inspect the upper layers of Ethernet packets and determine if they can pass. This allows application layer filtering, but also means that these firewalls do not allow Modbus programming commands. These firewalls are slower than the current type and are not common as yet.

Setting Up a Firewall

The methodology used for setting up a firewall is important.There are two ways to set up a firewall:

- allow all and then deny specific items
- deny all and then allow specific items

The method of *deny all* is the more secure, because it restricts even those cases you had not thought of. This is, therefore, the recommended setup method.

Access Control Lists

An access control list is implemented in layer 3 switches (see *p. 60*) and some layer 2 switches. It provides a filtering service similar to a firewall, but is based on a source/destination port or VLAN (see *p. 57*), instead of an IP address. It can be used at lower levels of a network (on the plant floor) to prevent access from one plant area to another. Once an access control list is set up, the system stops all types of access, for example, a person accidentally trying to connect to a PLC in the next area of the plant. The setup method is the same as for a firewall.

Port Security

The Schneider NxS272 device is able to protect each port using port security. Port security functions similarly to an access control list, but limits incoming connections based on a MAC address. Settings can be made to control who has access; every address or only a single address. If an invalid address is detected, settings can control the response; no response, trap or disable. Settings are made using the web address.

PLC Access Control

The Ethernet ports of the Quantum/Premium PLCs and ETG Gateway support access control lists for Modbus messaging. They allow you to configure IP addresses that can send Modbus requests to the PLC. They do not allow access to other protocols. Use care when setting access control because it restricts the functioning of active Web pages that use Modbus to retrieve data

Security Issues with Wireless

Wireless networks suffer a great security disadvantage when compared to traditional networks. Because a wireless network transmits over radio waves, it is easier to get unauthorized physical access to it.

These options for wireless systems exist in automation systems:

- traditional wireless systems for Serial networks, Modbus Plus and custom Ethernet solutions
- wireless Ethernet based on office standards

Systems based on non-standard wireless are more difficult to intercept since they do not use standard protocols. However, systems using office-based wireless can be intercepted using any laptop computer with a wireless connection, putting them more at risk.

Each wireless network is given an SSID, or network name, to identify it. Normally, the SSID chosen is a logical name. Do not choose a logical name such as the hardware vendor or your company name; this gives information about the network.

Access Points

An access point (software or a device) provides the connection hub for a wireless device connected to a cabled LAN. Access points have a setting of broadcast SSID. If this is set to on, the network name is broadcast and it appears as a choice to computers trying to connect. Disable the broadcast. This requires all computers to be pre-configured with the SSID in order to connect to the network. Most wireless networks use a DCHP server to assign IP addresses to clients. Configure the server to give IP addresses to specific Modbus Plus addresses. Do not configure any additional spare addresses. Limit access to known MAC addresses. Access points can be set up to allow only known IP and MAC addresses to connect. The MAC address on most PCs, especially laptops, can be changed to match one existing on the network.

WEP

Wired equivalent privacy (WEP) secures the network by encrypting data transmitted over radio waves so that anyone who wishes cannot simply listen to it. WEP should be turned on. Choose a WEP key, which allows you to listen to the network. Always generate a random WEP key; never use a key based on a word. The algorithms for generating keys from a word are known and programs exist to decipher word-based WEP keys. Therefore, a word-based WEP key is not secure; it can take from only 3 hours up to a few days to crack.

VPN and Firewalls

The combination of VPN and firewalls is the best security solution, but it is costly in terms of management time. Run a VPN client on the laptops and a VPN endpoint where the wireless network meets the main network. This adds additional encryption (stronger than WEP) to the data being transmitted. Run a firewall between the VPN endpoint and the rest of the network to further restrict access.

Services Overview

3

At a Glance

Overview

This chapter gives you the information you need to select the correct Transparent Ready service for each task in your automation system. It provides information about the benefits and limits of each service, and it discusses the operation of devices that use the service.

Note: The Unity performance data used in this chapter are based on version 2.0 of the software. Other Unity versions may be significantly different.

What's in this Chapter?

This chapter contains the following sections:

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3.3	Modbus Messaging	179
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3.1 Evaluating System Requirements

At a Glance

Overview

This section provides an overview of Transparent Ready services that support Ethernet communications at each level within the plant. It also describes how to evaluate your communications requirements and select the most appropriate services.

What's in this Section?

This section contains the following topics:

Topic	Page
Common Services at each Level in the Plant	155
Company Level Communication	156
Inter-PLC Level	157
Field Level Communications	157
Communication Service Selection	158
Transparent Ready Support Services and Protocols	161

Common Services at each Level in the Plant

Summary

Transparent Ready industrial products can be integrated into architectures based on the universal Ethernet TCP/IP network. No additional interfaces are required. The basic architecture below shows the various communication levels and functions required by industrial applications to meet the data exchange requirements of a plant:

Communications may take place at four levels:

- company level communication (see *p. 156*)—between the control system products and the manufacturing execution system (MES) or enterprise resource planning (ERP) supervision or information systems
- inter-PLC level communication (see *p. 157*)—for programming, diagnostics, and data transfer as well as communication between PLCs to synchronize applications
- field level communication (see *p. 157*)—between PLCs, PCs, and field devices
- transparent remote communication—remote communication via the Internet, telephone, or radio link

Company Level Communication

MSE/ERP Systems and PLCs

Company level communications use standard infrastructures and protocols to exchange high volumes of data with project management systems. In some cases, the PLC must adapt to a protocol specific to the connected system. Response times are not critical. The Transparent Ready services used are:

- HTTP communication to display data and send commands via Web pages
- data exchange using the OPC standard via an OFS data server (see *p. 256*)
- Modbus TCP/IP messaging (see *p. 179*)
- TCP open
- email transmission (see *p. 217*)
- direct publication in relational databases via the FactoryCast HMI active Web server (see *p. 236*)

Supervision Systems and PLCs

Company level communications may transfer high volumes of data from a corporate system to a group of PLCs. Response times generally need to be in the 0.5 to 2 s range. The Transparent Ready services used are:

- data exchanges using the OPC standard via an OFS data server (see *p. 256*)
- Modbus TCP/IP messaging (see *p. 179*)
- TCP open
- HTTP communication, integrated in the supervision system to display Web pages from the field devices in supervision pages

HMI Applications and PLCs/Field Devices

A basic HMI application must notify maintenance personnel of an event and let them view the status of a field device. The Transparent Ready services used are:

- email notification
- data display and transmission commands via Web pages

SNMP

The standard network management protocol (SNMP) can be used from a network management station to monitor, control, and perform diagnostics on all components in the Ethernet architecture (see *p. 244*).

Inter-PLC Level

Data Transfer Communication

When data is sent in point-to-point mode according to PLC programming algorithms and the required response times are in the 200 ms to 1 s range, the main Transparent Ready service to be used is Modbus TCP/IP messaging (see *p. 179*).

Synchronizing Applications

Broadcast communication uses real-time exchanges to synchronize several applications. Data is exchanged in low volumes. Response times in the10 to 500 ms range are required. The Transparent Ready Global Data service (see *p. 197*) is particularly suitable for synchronized data exchanges.

Field Level Communications

Field PCs and Operator Terminal Communication

Field level communication is used to configure, monitor, and maintain field devices for diagnostics and monitoring. Communication procedures must be simple so that less qualified personnel can access first-level diagnostics from a standard PC.

The most suitable Transparent Ready service is the display of diagnostic and customized Web pages (see *p. 223*).

Modbus and/or other industrial fieldbus protocols are used to control field devices.

Communication Service Selection

Summary

The following description of services (and the services tables that follow in the next discussion) can help you decide which services are best for your application.

I/O Scanning

The I/O scanning service allows you to exchange information repetitively between one central device and many remote devices without the need for special programming in either device.

It is used when you want to exchange data repetitively and at a fast rate (every 1 ms to 5 s). A typical example of a device that can use the I/O scanning service is a barcode reader that needs to scan all package labels as they travel along a fast-moving conveyor belt.

For details, see *p. 166*.

Modbus Messaging

The Modbus messaging service comprises client and server services. The client initiates a request to the server using the Modbus protocol; the server responds to the client's request, resulting in information exchange. Modbus messaging supports both reading and writing of data, as well as a set of programming commands.

Modbus messaging should be used when data needs to be exchanged between two devices at irregular intervals or infrequent periods. An example is a command to start a process or report on the completion of a process. Modbus messaging lets you initiate communications only when they are required, making more efficient use of your network and device resources.

For details, see *p. 179*.

Global Data

The global data service allows a device to publish data to a group of devices on the network. Devices in this distribution group can be configured to subscribe to the published data.

The global data service should be used when a device contains status information that more than one other device on the network needs to receive. The publishing device uses multicasting to efficiently send information across the network to its distribution group.

For details, see *p. 197*.

Faulty Device Replacement

The FDR service allows a central device (the FDR server) to store configuration parameters for remote devices on the network. If a remote device fails, the server automatically passes the stored configuration parameters on to a replacement device so that it can operate using the same configuration parameters as the failed device. The replacement is accomplished without manually configuring the parameters.

The FDR service should be used for all devices that are connected to an automation network. It reduces the need for service personnel to keep configuration records on hand, and it prevents human error in entering the new configuration.

For details, see *p. 204*.

Time Synchronization

The time synchronization service provides distribution of a central time source to multiple devices on the network. Accurate time in all devices allows you to properly synchronize events and manage the order of operations across a plant.

The time synchronization service should be used in any environment where timing plays an important role in operations. It eliminates the need to manually set the time on each network device. Also the accuracy can be as close as 1 ms in all devices, a level of precision that cannot be achieved when you set the time manually.

For details, see *p. 208*.

Electronic Mail Notification

The electronic mail notification service allows service personnel to be notified of the plant status via email. The email may include process data, production reports, alarms, events, and other information needed to evaluate plant status. A device with the email service can automatically create short electronic mail messages that can use predefined recipients, email addresses, and message subjects. The message body can be dynamically modified to include current plant data and other text.

The electronic mail notification service is used whenever email notification is a convenient communication option for informing someone of plant status, operation reports, or maintenance requirements. In this case, you are conveniently notified about maintenance, eliminating the need of regularly checking the equipment to know when it needs to be serviced. Because of potential delays, this service is not recommended for time-critical messages where short response times and quick intervention are important.

For details, see *p. 217*.

Embedded Diagnostics (Standard Web Services)

Embedded diagnostics can be used to execute diagnostic and maintenance functions locally and remotely with a simple Internet browser. The embedded diagnostics service uses an embedded Web server and a real-time data server. All data is presented in HTML (standard Web) format, which can be accessed from any Internet browser.

This service is a convenient way to monitor the health of devices on the network and operational and configuration information. Some automation devices support remote configuration via Web pages. For example, Altivar drives provide access to current speed information and allow acceleration rates to be configured through their Website.

For details, see *p. 223*.

Web/FactoryCast

Using a simple Internet browser, the FactoryCast Web server provides all the benefits of a standard embedded Web server service with the ability to control, configure, and monitor plant data locally and remotely. Monitoring and control can be enhanced with user-customized Web pages.

The Web/FactoryCast service is used to display and modify all plant variables in real time. It lets you create hyperlinks to external Web servers that can include plant documentation. The FactoryCast HMI Web incorporates an active Web server in the device, provides better Web pages, supports more clients, and allows database connectivity.

For details, see *p. 230*.

Transparent Ready Support Services and Protocols

SNMP

The SNMP service is for managing networks. It is a network management system that uses SNMP-compliant devices that are queried for information about themselves and the network. SNMP is in almost every Ethernet device and should be used as the basis for most network management systems. It can be used to discover, monitor, and configure devices on a network. SNMP is normally used to transfer device and network status, not plant status.

For details, see *p. 244*.

FTP

FTP is a method for exchanging files between devices over a network. Almost all operating systems today include an FTP client or server functionality, making file transfers from one device to the next an easy task. Many network devices implement FTP as a standard method for transferring information to update its internal software or firmware.

For details, see *p. 243*.

TFTP

TFTP is a simpler file transfer protocol than FTP, typically used for small file transfers and by less complex devices.

For details, see *p. 246*.

Telnet

The Telnet protocol provides an interactive client-host type communication session where you can type commands to view or manipulate a remote device. It is a text-based user interface that is integrated with many devices today. Telnet may be used to configure simple devices such as switches, routers, and serial-to-Ethernet bridges.

For details, see *p. 247*.

Plant Data Transfer Services

Service	Level, Common Use	Response Time	Data Transfer Frequency	Exchange Confirmation	Examples	Communications Topology
I/O scanning	field device and PLC-to-PLC levels 2 and 3	10 ms+	1 ms – 5 s periodic	I/O scanner health status for data transfer and fallback values. Acknowledgment of each data transfer with retry mechanism	controlling Advantys I/O plant status transfer between PLCs	central scanner device exchanging data with one or more remote devices
Modbus messaging	field devices, PLC-to-PLC, and supervision levels 1, 2, and 3	50 ms+	occasional or nonperiodic (exception reports)	acknowledgment of each data transfer with retry mechanism	confirmation of process completion SCADA/HMI communications	Client device-to-server device
Global data	PLC-to-PLC level 2	20 ms+	10 ms – 30 s periodic	none	device status distribution to a group of devices	many publishing devices-to-many subscribing devices
TCP open	field device-to-PLC, PLC-to-PLC, PLC-to-supervisor levels 1, 2, and 3	100 ms+	100 ms+ or exception based	user configurable	programming a new communications protocol (e.g., Ethernet IP) to communicate with a third-party device	one client-to-one server

Remote Data Transfer Services

Service	Level, Common Use	Response Time	Data Transfer Frequency	Exchange Confirmation	Examples	Communications Topology
Electronic mail notification	company level level 1	minutes	exception report, up to several/min	send confirmation, no delivery confirmation	maintenance reminders production reports	one email client-to-many recipients
FactoryCast HMI email						
FactoryCast HMI database connectivity	company level level 1	seconds	1 s – 30 min	-	sending production reports and data directly to a database	one device-to-database
OPC	company level level 1	50 ms - seconds	exception report or periodic	confirmation per transaction	SCADA server-to-SCADA clients plant monitoring system-to-plant devices	central OPC server with Modbus TCPIP to plant devices, then OPC communicates plant data to other SCADA or HMI applications

Diagnostic Services

Service	Recipient of Diagnostics	Single- or Multiple-device Diagnostics	Device or Plant Diagnostics	Examples	Communications Topology
Embedded diagnostics	people	single	internal device information	obtaining module health and configuration information remotely with a Web browser	several Web browser clients
FactoryCast	people	single or multiple	plant information	displaying plant operation status with simple customized Web pages	several Web browser clients
FactoryCast HMI	people/ machines	single or multiple	plant information	remotely viewing plant status efficiently with advanced customized Web pages and applications	many Web browser clients
SNMP	machines	single or multiple	device network information	monitoring plant network status by network management (HP Open view)	network management system-to-many SNMP devices
Telnet	people	single	device	monitoring internal device status	one Telnet client-to-Telnet server in a device

Configuration Services

Service	Configuration of ...	Configured by ...	Example
FDR	devices on the network by an FDR server	an FDR server, providing automatic configuration of client devices	automatically configuring an Ethernet distributed I/O device's operating parameters after the device is connected to the network
Embedded diagnostics	a device connected to by a user	a person	configuring a variable speed drive's operating parameters with a Web browser
SNMP	a device connected to by a user or a network management system	a person or a network management system	configuring network infrastructure component parameters with a network management system
Telnet	a device connected to by a user	a person	configuring the operating parameters of a serial-to-Ethernet bridge network with a direct connection

Checking Service Compatibility

Before selecting a service, make sure that the devices involved in the data transfer support the desired service. If a device does not support the selected service, you need to make another service choice. Choosing another, perhaps less optimized, service does not mean that the interaction between the devices cannot be achieved but only that the use of the network and device resources may not be optimal. Once you have selected the service, record it in the list of plant communications.

Combining Data Transfers

Once all services are selected, interactions between like devices using the same service may be combined. This may not be appropriate for all interactions (e.g., FTP to transfer files for one purpose cannot be combined with a separate FTP transfer) but may be beneficial for others. For example, using Modbus messaging to transfer the status of 10 different items can be combined into a single transfer.

System Evaluation

Perform a system performance evaluation to be sure that the combination of all data transfers does not overload any service or device. An overload may result in lower performance from a service or a complete failure of the data transfers.

Network Design

Your network must either be designed to support the services you select or, if the network is already in place, checked to verify that it can transport the required services. Items to be checked include:

- networks, subnets (see *p. 132*) and addressing (see *p. 130*)
- bandwidth
- routers (see *p. 139*) and firewalls (see *p. 150*)
- RAS (see *p. 144*)

3.2 I/O Scanning Service

At a Glance

Overview

This section describes the I/O scanning service and how it is used to exchange data between a central device and many remote devices.

What's in this Section?

This section contains the following topics:

Topic	Page
I/O Scanning Service Description	167
I/O Scanner Operation	169
Repetition Rates	174
Some Common Fault Conditions	176
Response Times	177

I/O Scanning Service Description

The I/O Scanning Service

The I/O scanning service is a stand-alone communications task that exchanges register data between one device running the service and many remote devices on the network using Modbus TCP. The service requires only a simple configuration operation in the I/O scanner device; no special programming is required in either the I/O scanner device or the remote devices.

The remote device must be a Modbus TCP/IP server. Examples of remote devices include:

- distributed I/O such as Advantys STB and Momentum
- intelligent devices such as Altivar drives and Sepam circuit monitors
- PLC devices such as Quantum and Premium
- Modbus serial devices such as Lt6 motor relays that are accessed through a bridge
- any third-party device that is a Modbus TCP/IP server

The I/O scanner reads and writes data repetitively in a user-configurable period ranging from 20 ms to 5 s. These read/write exchanges generate a load on the network. For this reason, the I/O scanner is best suited for critical periodic operations.

The I/O scanner is configured with a list of devices, data areas, and the rate at which the register data exchange takes place. The scanner establishes a connection to the remote device and exchanges data at the configured rate. The I/O scanner maintains the connection to the remote device while handling any errors that occur. For each remote device, a report is sent back to the application, indicating whether the data is being transferred within the specified exchange rate.

I/O Scanner Characteristics

I/O scanner is an open system; you are not bound to any particular platform or to the same brand name. The I/O scanner system consists of two parts, the scanning device and the remote device(s).

The scanning device has no control over the remote device. For example, if the device fails, the I/O scanning device cannot issue its fallback state. The I/O scanning device has the ability to issue what state its application value should have in the case of lost communication to the remote device. There are no individual configurable parameter screens available for the remote devices. You may be able to do an initial write to the remote device to configure it, if this is supported by the remote device. However, you need to disable that entry after the initial configuration because you don't want the write request to take place at every configured repetitive rate. The I/O scanner device does not have any specific information about the remote device other than its IP address. Due to this open system, you have no control over the remote device's response time. WIth other I/O systems, you are able to determine the cyclic time at which the information is expected. With I/O scanner, there is no set value as to when that register data exchange takes place; It may be different for each remote device.

Some other characteristics of I/O scanner are:

- maximum transferable data block sizes of 100 words written and 125 words read per entry
- maximum number of words read or written is 4,000
- multiple data blocks that can be exchanged with a single remote device
- a user-configurable repetitive data transfer rate (see *p. 174*) ranging from 1 ms to 5 s
- fault reporting for each remote device
- a data exchange enable/disable for each remote device

Each entry in the I/O scanner configuration creates a new socket, including multiple entries to the same remote device.

Remote Device I/O Scanning Requirements

- Modbus TCP/IP messaging support or Modbus serial slave if a serial-to-Ethernet bridge is used
- supports Modbus function codes 3 (read registers), 16 (write registers) and 23 (read/write registers), depending on data that is exchanged

Applications

The I/O scanning service should be used when a central device needs to exchange data (either read or write data) with a remote device at a fixed, reasonably fast rate. Suitable applications include:

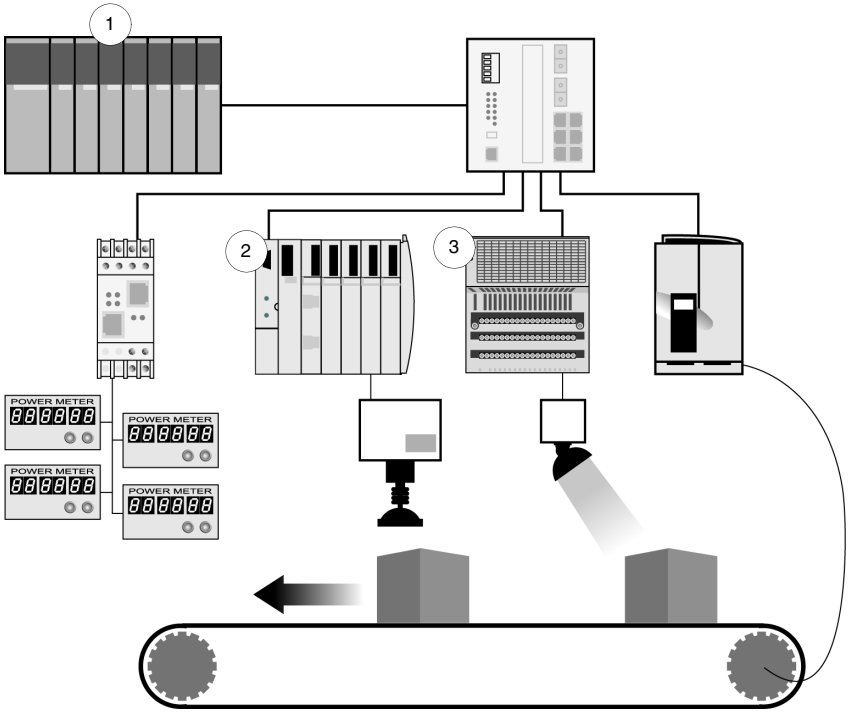
- fast repetitive communications
- applications that call for communication between one device and many remote devices, where different data is exchanged with different remote devices
- applications that need to exchange data to more devices than is possible using the existing COMM blocks
- automatic error handling
- controlling I/O devices
- devices that need to exchange the same data with many devices but that do not support the global data service (see *p. 197*)

Because of the network and device load produced by its data exchanges, the I/O scanning service should not be used for nonperiodic communications, event-triggered actions, report generation, or event notification because of the network and device load produced by its data exchanges. The Modbus messaging service should be used in these situations.

I/O Scanner Operation

Summary

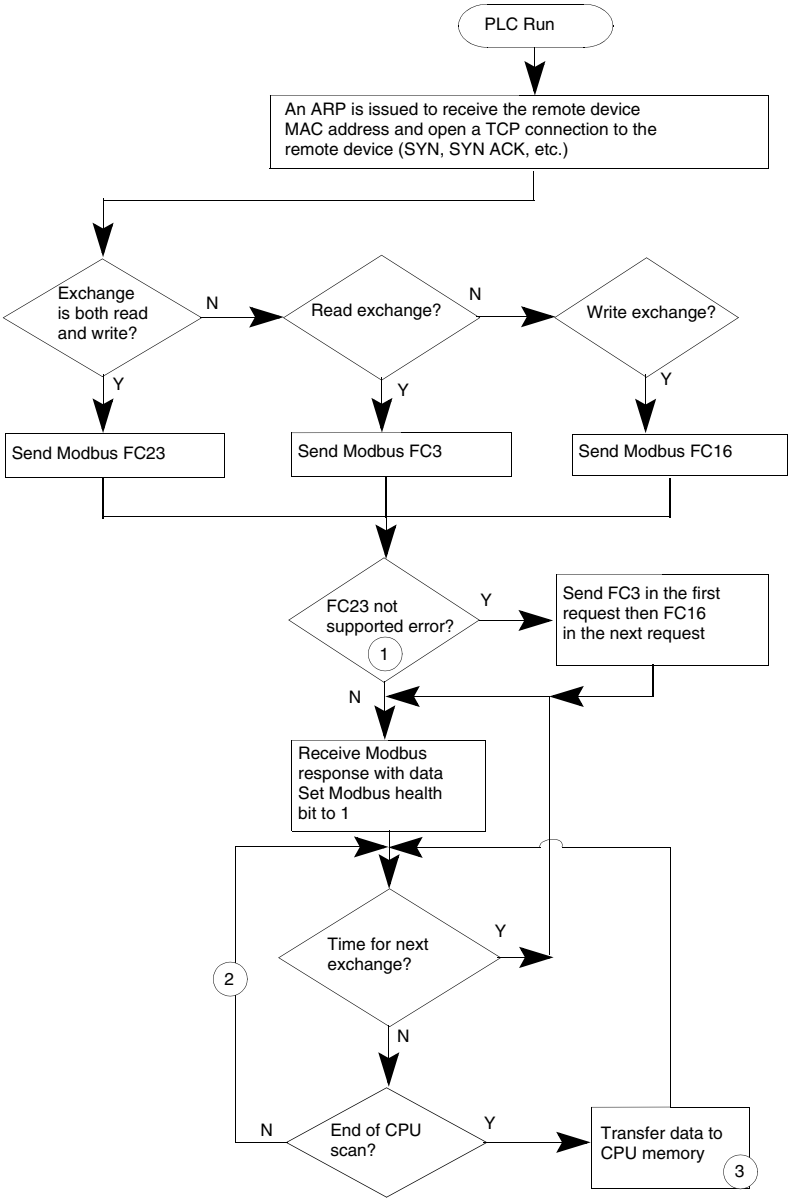
The I/O scanning service is implemented as a separate stand-alone communications task in either an Ethernet communication module or in a CPU with an embedded Ethernet port. After the service is configured, it receives a list of devices to scan and memory zones where it can read and write in the remote devices. It then begins to exchange data with each remote device. Each entry in the I/O scanner configuration runs independently, even if multiple entries exchange data with a single remote device.



1 a controller
2 an output device
3 a reading device

Service Operation

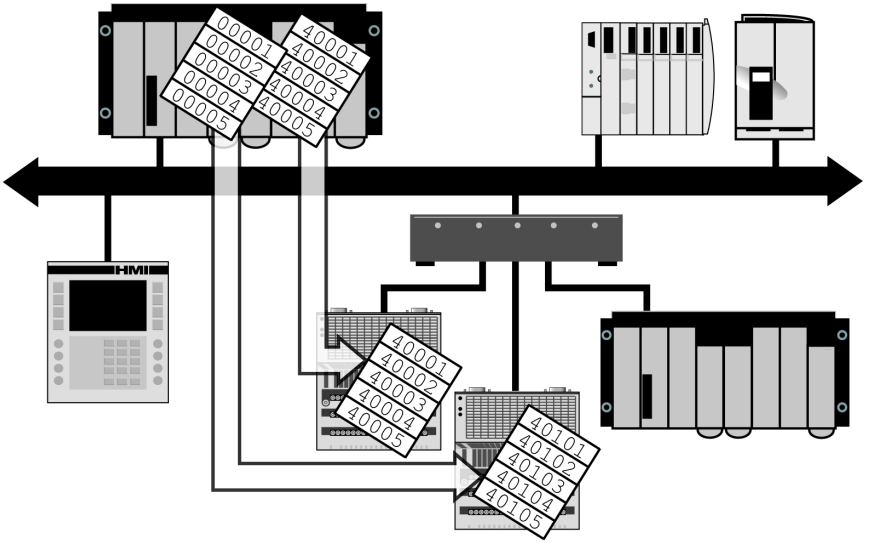
Each independent information exchange is represented by a separate entry in the I/O scanner configuration table. The following flow chart illustrates how the I/O scanner executes one information exchange.



1 If the remote device does not support FC23, the I/O scanner uses FC3 and FC16 to execute the data transfer. When this happens, the read operation is performed in the first exchange and the write operation is performed in the next exchange. The total read/write operation takes twice as long as the time required for the FC23 operation to execute.
2 The timing of this loop is affected by the repetition rate.
3 All I/O scanner entries exchange data with the CPU at the end of the scan.

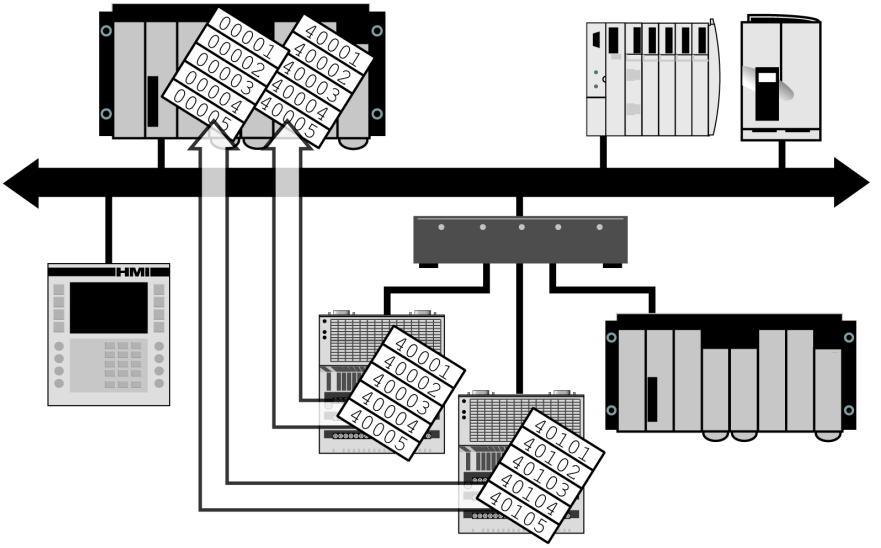
Write Operations

The I/O scanning service writes data from a memory zone in the I/O scanner device to a memory zone in the remote device. Depending on the I/O scanner device, the memory holding the values to be sent may be 16-bit registers (%MW or 4x) or blocks of bits (%M or 0x). The data is always written to 16-bit registers in the remote devices.



Read Operations

The I/O scanner device reads data from memory zones in the remote devices to gather field device or input status. The remote devices always store this status data in 16-bit registers. After the data is read, it can be stored in 16-bit registers (%MW or 4x) or blocks of bits (%M or 0x) in the I/O scanner device's memory.



Error Handling

If there is a loss of communication with one or more remote devices, the I/O scanner applies configured fallback values to the corresponding I/O scanner memory areas. If a communication failure occurs, the I/O scanner does not control remote device operation. These devices handle their own fallback states.

Enable/Disable

Enable/disable allows you to start and stop the data exchange between a remote device and the I/O scanner device. Four double-word registers are designated to the 128 entries in the I/O scanner configuration. Each I/O scanner entry is controlled by a single bit. When a control bit is turned on, the data exchange is disabled and the health bit is turned off after the time-out period expires. At this point, the TCP socket to the remote device is closed.

This feature can be used to limit the number of concurrent sockets to a remote device. For example, in a Modbus Ethernet-to-serial bridge, which supports a limited number of concurrent TCP sockets, turning on the control bit that was turned off opens a new socket and enables the I/O scanning exchange to resume. However, the health bit remains off until the first data exchange with the remote device is completed successfully.

Health Bit Operation	The health bit indicates whether or not a data exchange has been successful. If a fault occurs but is resolved within the health time-out period, the bit stays on. The health bit turns off if the data exchange is not complete/resolved successfully in the health time-out period. The health timeout should be longer than the repetetive rate. For a Quantum NOE Ethernet module, the health timeout must also be longer than the CPU scan time, due to the link with the CPU scan cycles.
Diagnostic Word Support	A diagnostic word is provided for each I/O scanner exchange. This word provides additional diagnostic information on fault codes. Implementation is platform-specific.
TCP Socket Usage	The I/O scanner opens a single TCP socket for each configured data exchange. A device configured for multiple exchanges has multiple sockets. The I/O scanner uses source TCP port numbers in the range of 3000 - 4000.

Repetition Rates

Summary

The repetition rate is the rate at which you configure the I/O scanning service to exchange data.

Effective Repetition Rates

The *effective* repetition rate is the actual rate at which data is polled from the remote devices. This rate may differ from the configured repetition rate on different PLC platforms and option modules. The effective rate is determined by the way the I/O scanning service is installed. The effective repetition rate is limited by:

- the I/O scanning service timer
- remote device response times
- CPU scan time and data transfer time

A new request cannot be issued until after the remote device responds to the previous request.

Repetition Rates/ Internal Clocks

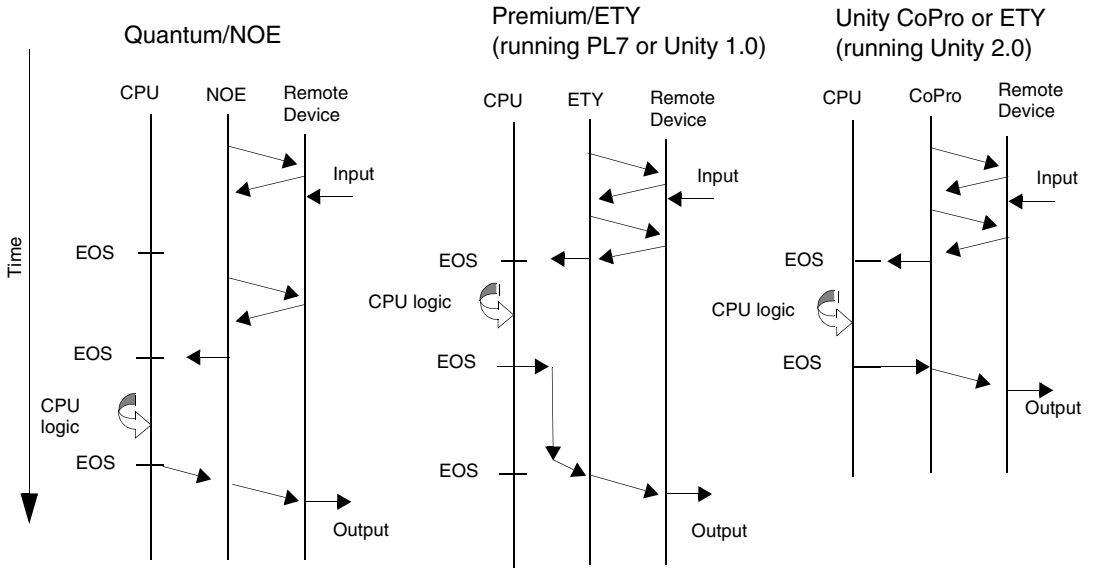
Repetition rates are limited by the I/O scanner device. A Quantum NOE Ethernet communications module has a 17 ms clock rate. A Premium ETY Ethernet communications module or a Unity CoPro CPU with an embedded Ethernet port (Quantum or Premium) has a 10 ms clock rate. The clock rate limits the time resolution in which an I/O scanner request is sent to a remote device.

When the configured repetition rate is 0 ms, the system sends requests as fast as possible. In a Quantum NOE system, requests are sent after the data is transferred at each end of scan (EOS). A Premium or Copro system sends requests as frequently as a remote device can respond to the previous request.

When the repetition rate is configured for a value greater than 0 ms, the rate is rounded up to a multiple of 10 ms on a Premium or a Unity Copro system or 17 ms on a Quantum system. For example, a Premium system with a configured repetition rate of 35 ms sends a request every 40 ms (providing the end device has finished responding). A Quantum NOE system configured for a 25 ms repetition rate sends requests either every 34 ms or once per PLC scan, whichever is greater.

A Comparative Example

The following chart compares effective repetition rates for Quantum, Premium, and Unity CoPro systems over multiple scans:



- A Quantum PLC with an NOE Ethernet communications module exchanges data with a remote device once per CPU scan. This limits the effective repetition rate to a value greater than one PLC scan cycle.
- A Premium PLC with an ETY Ethernet communications module (in a PL7 or Unity 1.0 environment) exchanges data at the configured repetition rate (assuming that the device can answer within this time period) and exchanges the data with the CPU on each EOS cycle. The output cycle requires an additional CPU scan to transfer the data to the ETY module.
- A Unity CoPro CPU with an embedded Ethernet port or a Premium CPU with an ETY module in a Unity environment transfers data at the configured repetition rate (assuming that the device is able to answer within this time period).

Note: Data values may be exchanged with the remote device multiple times per CPU scan. The last value read from the remote device is sent to the CPU at the next EOS, and the value written to the remote device is the value from the CPU at the previous EOS.

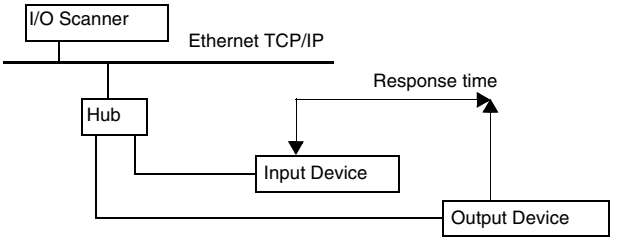
Some Common Fault Conditions

Condition	Cause	Response
A device is not found on the network.		The I/O scanner device issuing the ARP requests attempts to locate the remote device. Requests are sent every 30 s.
Socket overload: a remote device refuses to accept a TCP socket connection.	This error is commonly seen on bridges with many entries in the I/O scanner or in low-end devices that support a limited number of sockets. It occurs as an I/O scanner health bit goes off at random intervals.	If the remote device is unable to open the TCP socket, the I/O scanner device attempts to open a socket every second. If the problem persists, you may be able to correct it by using the enable/disable feature (see *p. 172*). To free up sockets, limit the number of I/O scanner data exchanges operating to the same IP address.
A remote device refuses FC23.	If you are using pre-Unity 2.0 I/O scanner systems or end devices that do not send back the correct error code, the I/O scanner fails. It continues to send FC23 and continues to fail.	When this failure occurs, the device sends back a Modbus exception with an error code corresponding to function code not supported. The I/O scanner falls back to a combination of FC3 andFC16.
A request or response packet is lost, or the socket is corrupted and unable to transfer data.		Normal TCP socket transmissions occur on the first retransmission by the I/O scanner device; after three retransmissions, the socket is reset and a new ARP is issued. The loss of an Ethernet packet can switch off the health bit unless there is sufficient time to reissue the packet and receive an answer before the health time-out period has expired. The retry time for a lost or corrupted packet varies with different versions of the product. Early versions retried at 800 ms, 600 ms, 1.5 s, and 3 s. Newer versions base their retries on the previous response times, but in a good system approximately 50 ms, 800 ms, and 1.5 s can be achieved.

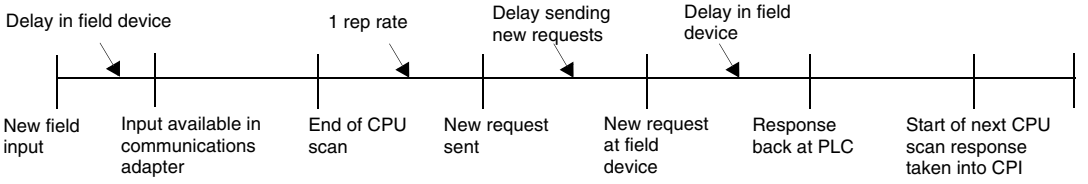
Response Times

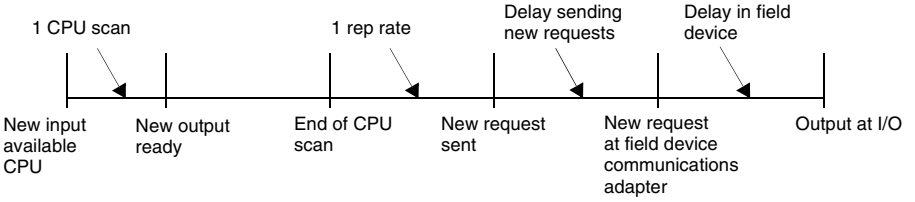
The I/O scanner system response time depends on:

- the CPU scan time
- the time for the scanned device to respond to the request
- the activation time for the scanned device for a new input or output



The following chart illustrates the performance of a Quantum I/O scanner, round trip from the field input to the CPU and back to the output.

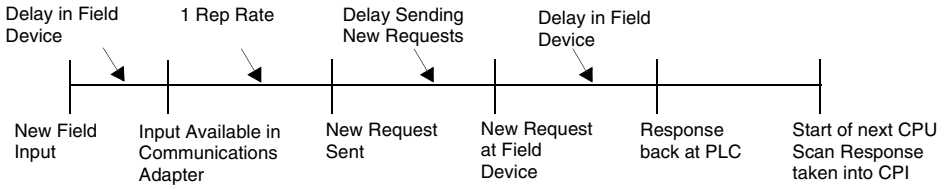

Delay in field device
1 rep rate
Delay sending new requests
Delay in field device
New field input
Input available in communications adapter
End of CPU scan
New request sent
New request at field device
Response back at PLC
Start of next CPU scan response taken into CPI

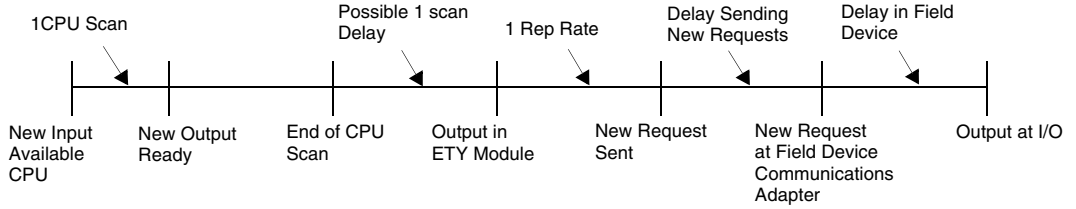


For a configured repetition rate of 0 ms, the formula for the worst-case time is:

- *total time* = Tmod + 1 CPU scan + [if (T1 > 1 CPU scan) then (T1 + 1 CPU scan) Else (1 CPU scan)] + 1 CPU scan + 0.3 ms * no Requests + Tmod
- T1 = 0.3 ms * number of requests + device response time

The following chart illustrates a Premium I/O scanner's performance, round-trip from the field input to the CPU and back to the output.


Delay in Field Device
1 Rep Rate
Delay Sending New Requests
Delay in Field Device
New Field Input
Input Available in Communications Adapter
New Request Sent
New Request at Field Device
Response back at PLC
Start of next CPU Scan Response taken into CPI



For a repetition rate of 0 ms, the formula for the worst-case time is:

- *total time* = Tmod + T1 + 1 CPU scan + 1 CPU scan + 1 CPU scan (for ETY only) + 0.3 ms *number of requests + Tmod
- T1 = 0.3 ms * number of requests + device response time

The following chart illustrates the typical I/O scanner response time from a field input on a scanned device to a field output activated at another scanned device due to PLC logic triggered from the first input. CPU scan time is ~50 ms. The scanned device response time is ~10 ms.

PLC System	**Number of Device Scanned**		
	1	**16**	**32**
Quantum or Premium with NOE/ETY (non-Unity)	110 ms	115 ms	125 ms
Quantum or Premium Unity CPU with embedded Ethernet port	100 ms	105 ms	115 ms

3.3 Modbus Messaging

At a Glance

Overview

This section describes the Modbus messaging service. This service handles the Modbus protocol and enables data transfers between network devices.

What's in this Section?

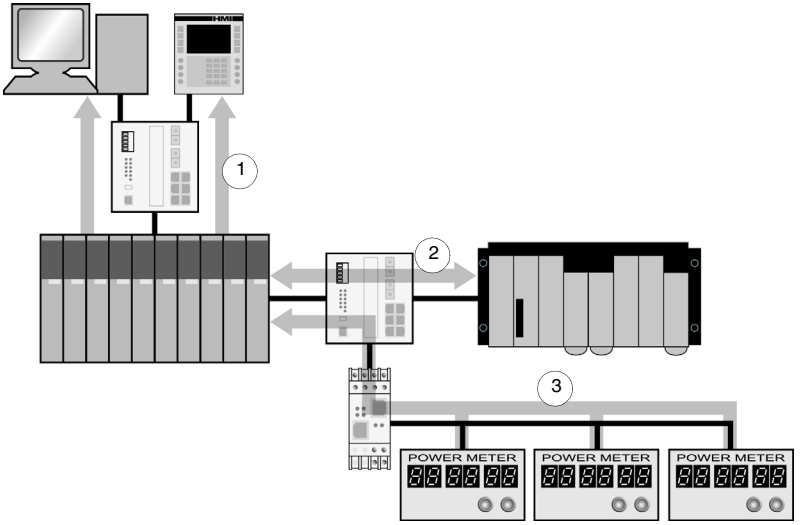
This section contains the following topics:

Topic	Page
Modbus Messaging Service Description	180
Devices that Support Ethernet Modbus Services	184
Modbus Client Operations in Quantum Systems	185
Modbus Client Operations in Premium Systems	186
Modbus Client Operations in Momentum Systems	188
Modbus Server Operations in Quantum Systems	189
Modbus Server Operations in Premium Systems	192
Modbus Server Operations in Momentum Systems	194
Modbus Servers and Socket Limits	195
Modbus Messaging Retry Times and Time-outs	196

Modbus Messaging Service Description

The Modbus Messaging Services

The Modbus messaging service handles the transfer of data or commands between two devices. One device is the client and the other is the server. The client initiates the request and the server responds to the request. These services use the Modbus protocol (or Modbus over TCP/IP in Ethernet applications) to support the data transfer between devices.



1 SCADA and HMI data requests
2 PLC data transfer
3 device data gathering

Modbus Communication Standard

Modbus has been the industrial communication standard since 1979. It is now combined with Ethernet TCP/IP to support Transparent Ready solutions.

Modbus over TCP/IP is a completely open Ethernet protocol. The development of a connection to Modbus TCP/IP requires no proprietary component or license purchase. The protocol may be easily combined with any device that supports a standard TCP/IP communication stack. Specifications can be obtained free of charge from *www.modbus.org*.

Modbus TCP Device Implementation

The Modbus application layer is very simple and universally recognized. Thousands of manufacturers are already implementing this protocol. Many have already developed Modbus TCP/IP connections, and many products are currently available. The simplicity of Modbus TCP/IP enables any small field device, such as an I/O module, to communicate over Ethernet without a powerful microprocessor or a large amount of internal memory.

Modbus TCP/IP

The same application protocol is used for Modbus serial link, Modbus Plus, and Modbus TCP. This interface routes messages from one network to another without changing the protocol. Because Modbus is implemented above the TCP/IP layer, you can also benefit from the IP routing, which enables devices located anywhere in the world to communicate regardless of the distance between them.

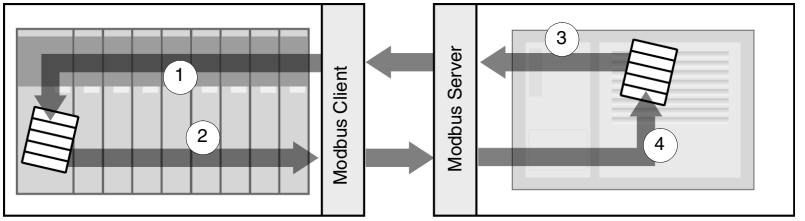
Schneider offers an entire range of gateways for interconnecting a Modbus TCP/IP network to already existing Modbus Plus or Modbus serial link networks. For further details, consult a Schneider Electric regional sales office. The IANA institute has assigned to Schneider port TCP 502, which is reserved for the Modbus protocol.

Modbus Messaging Summary

The transfer of information between a Modbus client and server is initiated when the client sends a request to the server to transfer information, to execute a command, or to perform one of many other possible functions.

After the server receives the request, it executes the command or retrieves the required data from its memory. The server then responds to the client by either acknowledging that the command is complete or providing the requested data.

The system response time is limited by two main factors, the time required for the client to send the request/receive the response and the ability of the server to answer within a specific amount of time.

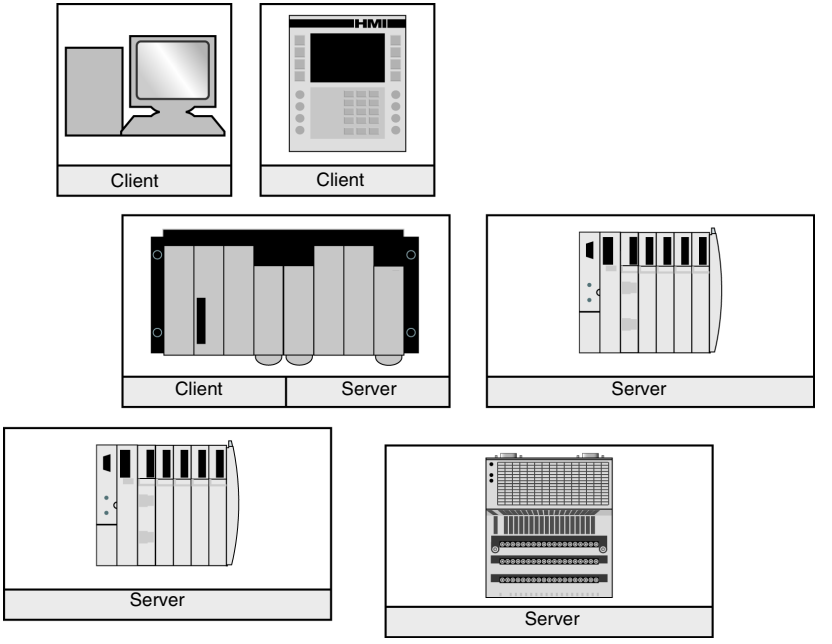


1 retrieved data
2 client request
3 server response
4 data retrieval

A device may implement a Modbus client service, a Modbus server service, or both, depending on the requirements of the device. A client is able to initiate Modbus messaging requests to one or more servers. The server responds to requests received from one or more clients.

A typical HMI or SCADA application implements a client service to initiate communications with PLCs and other devices for information gathering. An I/O device implements a server service so that other devices can read and write its I/O values. Because the device does not need to initiate communications, it does not implement a client service.

A PLC implements both client and server services so that it can initiate communications to other PLCs and I/O devices and respond to requests from other PLCs, SCADA, HMIs and other devices.



What a Modbus Client Service Provides

A device that implements the Modbus client service can initiate Modbus messaging requests to another device that implements a Modbus server. These requests allow the client to retrieve data from or send commands to the remote device.

What a Modbus Server Service Provides

A device that implements the Modbus server service can respond to requests from any Modbus client. The Modbus server service allows a device to make all its internal and I/O data available to remote devices for both reading and control.

Modbus Function Codes

The Modbus protocol is a collection of function codes, where each code defines a specific action for the server to perform. The ability of a device to perform read and write functions is determined by the Modbus function codes that are implemented by the server.

The Modbus protocol is based on five memory areas inside the device.

Memory Area	Description
0x or %M	Memory bits or output bits
1x or %I	Input bits

Memory Area	Description
3x or %IW	Input words
4x or %MW	Memory words or output words
6x	Extended memory area

In addition to the function codes for reading and writing data within these areas, there are codes for statistics, programming, device identification, and exception responses. The Modbus server can make data available based on the following limits:

- Read: 125 words or registers
- Write: 100 words or registers

When to Use the Client

A Modbus client should be used when data needs to be exchanged between two devices at irregular or infrequent intervals such as when an event occurs. The client allows a request to be triggered by the application code (in the case of a PLC or SCADA) or by an internal timer (for a SCADA or an HMI). This allows you to initiate communications only when required and provides a more efficient use of resources.

If the data must be exchanged at a short fixed rate, the I/O scanner service (see *p. 166*) should be used instead (if that service is supported by the client).

When to Use the Server

The Modbus server is accessed by either a Modbus client or an I/O scanner service and should be used to transfer plant information, commands, or other required data. The Modbus server provides real-time data transfer or access to data reports that are stored in its memory. The Modbus server answers any Modbus requests it receives. No additional configuration is necessary.

Any device that needs to exchange plant status, commands or data with other devices should implement a Modbus server. A device that implements the server can respond to requests sent from Modbus clients and make its internal I/O and data available to remote devices for reading and control. The device may be an I/O module, a drive, a power meter, a circuit breaker, a motor starter, or a PLC.

I/O modules are good examples of devices that implement a Modbus server service. As servers, input modules let other control devices read values from them, and output modules let control devices write values to them.

A PLC system implements both client and server services. The client service enables the PLC to communicate with other PLCs and I/O modules; the server service enables it to respond to requests from other PLCs, SCADA, HMIs and other devices. Devices that do not need to respond to data transfer requests should not need to implement a server service.

Devices that Support Ethernet Modbus Services

Device		Modbus Client	Modbus Server
Unity Pro Quantum	140CPU65150	X	X
	140CPU65160	X	X
	140NOE77101	X	X
	140NOE77111	X	X
	140NWM10000	X	X
Unity Pro Premium	TSXP571634M	X	X
	TSXP572634M	X	X
	TSXP573634M	X	X
	TSXP574634M	X	X
	TSXP575634M	X	X
	TSXETY4103	X	X
	TSXETY110WS	X	X
	TSXETY5103	X	X
	TSXWMY100	X	X
TSX Micro	TSXETZ410	X	X
	TSXETZ510	X	X
Momentum	171CCC96020	X	X
	171CCC96030	X	X
	171CCC98020	X	X
	171CCC98030	X	X
	171ENT11001	-	X
	171ENT11002	-	X
Twido	499TWD01100	X[1]	X[1]
Advantys STB	STBNIP2212	-	X
Altivar ATV38/58	VW3A58310	-	X
Power Logic Gateways/Bridges	EGX200	-	X[1]
	EGX400	-	X[1]
ConneXium Cabling systems	174CEV30020	X[1]	X[1]
	174CEV20030	X[1]	X[1]
	174CEV20040	X[1]	X[1]

[1] Device receives and sends Modbus messages as a gateway.

Modbus Client Operations in Quantum Systems

Limits

With Concept or Proworx programming software, an application on a Quantum system can initiate Modbus client communications using the following Modbus client blocks:

- MSTR
- READ_REG
- WRITE_REG
- C_READ_REG
- C_WRITE_REG

The Quantum PLC reads and writes to the 4x or%MW data area only. Up to 16 concurrent Modbus client blocks can be triggered by an NOE Ethernet communications module. If additional blocks are triggered, they are buffered until one or more active blocks complete their operations.

Quantum Modbus Client Operations

A Quantum Modbus client operates as follows:

Sequence	Event
1	The application triggers the Modbus client block.
2	The request is immediately sent to the NOE Ethernet communications module.
3	The NOE module checks if a TCP socket is connected to the destination device.
4	If a TCP socket is not connected, the NOE initializes a TCP socket and connects it to the destination device.
5	The NOE module sends the Modbus request.
6	The message travels across the network, and a network delay occurs.
7	The Modbus server receives the message.
8	The Modbus server responds to the request.
9	The message travels across the network, and a network delay occurs.
10	The NOE receives the response.
11	The next time the Modbus client block is reached in the code, the response is gathered from the NOE module and any new data is made available to the user application.
12	The NOE leaves the TCP socket open for future use.

Note: The NOE module keeps the TCP socket open until the other end closes it or the NOE module reaches its TCP socket limit. If one of these events occurs, the NOE closes any socket that has no outstanding requests on it.
Newer NOE modules can send multiple requests down a single TCP socket. Some older NOE modules may support only a single TCP socket per request and close the TCP socket after each exchange is completed.

Modbus Client Operations in Premium Systems

Limits

Using Unity Pro or PL7 programming software, an application on a Premium system can initiate Modbus client communications using the following Modbus client blocks:

- WRITE_VAR
- READ_VAR
- SEND_REQ
- DATA_EXCH

The Premium PLC limits the number of Modbus client communication blocks that can be triggered concurrently (based on CPU type). This limit applies to the total number of Modbus client request blocks per CPU and includes blocks triggered for the following messaging services:

- Modbus TCP/IP client
- Fipway
- Modbus serial
- Unitelway
- Ethway

If additional client blocks are triggered, an error message is returned to the application program.

Modbus client requests are limited as follows:

Client: family of processors	Ethernet Communications Mechanism	Number of Requests
Unity Pro v2.0 CoPro	ETY module or embedded port*	80*
Unity level 2 P57-xx	ETY module	32
Unity level 4 TSX574-xx	ETY module	64
PL7 level 2 TSX572-xx	ETY module	32
PL7 level 4 TSX574-xx	ETY module	64
* When the Unity 2.0 CoPro uses an embedded port, it can send 80 requests, but it can accept only eight replies per scan.		

Premium Modbus Client Operations

The Modbus client operates as follows:

Sequence	Event
1	The application triggers the Modbus client block.
2	The processor holds the request until the end of the current CPU scan.
3	The ETY module checks if a TCP socket is connected to the destination device.
4	If a TCP socket is not connected, the ETY module initializes a TCP socket and connects it to the destination device.
5	The ETY module sends the Modbus request.
6	The message travels across the network and a network delay occurs.
7	The Modbus server receives the message.
8	The Modbus server responds to the request.
9	The response travels across the network and a network delay occurs.
10	The ETY module receives the response.
11	The response is passed back to the CPU at the next phase (beginning of the next CPU scan).
12	The next time the Modbus client block is reached in the code the response and any new data is available to the user application.
13	The ETY leaves the TCP socket open for future use.

Note: The ETY module leaves the TCP socket open until the other end closes it or the ETY module reaches its limit of TCP sockets. At that point, the ETY module closes any socket that has no outstanding requests on it. The ETY module can send multiple requests down a single socket.

Modbus Client Operations in Momentum Systems

Limits

Using Unity Pro, Concept or Proworx programming software, an application running on a Momentum system can initiate Modbus client communications using the following Modbus client blocks:

- MSTR
- READ_REG
- WRITE_REG
- C_READ_REG
- C_WRITE_REG

The Momentum PLC reads and writes to 4x or %MW data register areas only. Up to 16 concurrent Modbus client blocks can be triggered. If an additional block is triggered, it returns an error code to the application.

Momentum Modbus Client Operations

A Momentum Modbus client operates as follows:

Sequence	Event
1	The application triggers a Modbus client block.
2	The processor holds the request until the end of the current CPU scan.
3	At the end of the current CPU scan, the Momentum PLC begins to open a socket to the destination device and a SYN message is sent.
4	The Modbus server responds with a SYN ACK.
5	At the end of the next CPU scan, the Momentum PLC receives the SYN ACK and opens the socket.
6	As soon as the socket is open, the Momentum sends the Modbus request.
7	The message travels across the network and a network delay occurs.
8	The Modbus server receives the message.
9	The Modbus server responds to the request.
10	The response travels across the network and a network delay occurs.
11	The Momentum receives the response.
12	At the end of the next CPU scan, the response is read into the Momentum and the socket is closed.
13	The next time the Modbus client block is reached in the code, the response and any new data is made available to the application.

Modbus Server Operations in Quantum Systems

Quantum Implementation

A Modbus server is implemented in either an NOE Ethernet communications module or an Ethernet port embedded in the Quantum PLC. The data to be accessed by the Modbus server is held in the PLC CPU memory. The interface between the NOE module or the embedded port and the CPU defines the Modbus server operation.

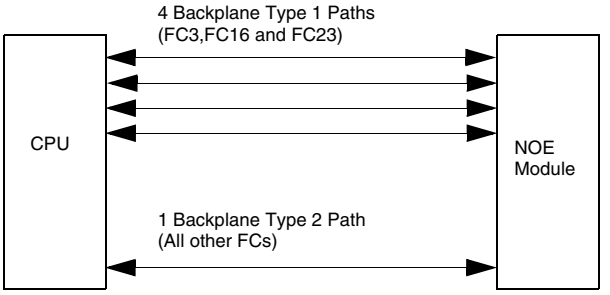
Quantum Modbus Server Operation

The Modbus server for Quantum systems operates as follows:

Sequence	Event
1	A Modbus client establishes a TCP socket to the NOE module or the embedded Ethernet port.
2	The Modbus client sends a request along the TCP socket.
3	The NOE module or the embedded Ethernet port receives the request and may acknowledge it.
4	The request is placed in the queue inside the module to be passed to the CPU. The CPU lets the NOE module/embedded Ethernet port access its memory at the end of the next CPU scan.
5	In the case of the NOE module, the NOE passes the request from the queue to the CPU in one of two possible ways: ● If the NOE requests a Modbus register read/write (FC3, FC16 or FC23), it reads the PLC's memory by using request type 1. ● If the NOE module requests any other Modbus function code, it passes the entire request to the CPU for processing type 2.
	In the case of the embedded Ethernet port, the request from the queue is passed to the CPU.
6	The NOE module/embedded Ethernet port immediately receives an answer to any request (except programming requests) sent to the CPU.
7	The NOE module/embedded Ethernet port sends the response back to the Modbus client.
8	The TCP socket is left open.

- Path type 1 requests give the NOE module direct memory access.
- Path type 2 requests pass the entire Modbus message to the CPU.

Depending on the system, the NOE module or the embedded port may respond to a different number of requests at the end of each CPU scan.The following diagram shows the five backplane paths between the NOE module and the CPU:



Concept/ Proworx Modbus Server Operation

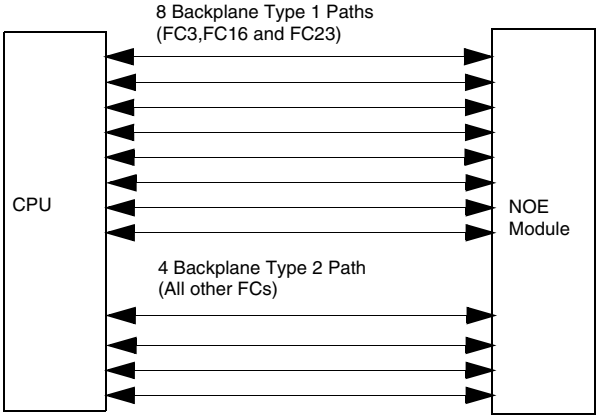
Each time the NOE module is serviced (once per CPU scan), it sends one request across each of the five paths. The type 1 backplane paths allow direct memory access to the CPU memory. The NOE module uses these paths to read/write 4x registers directly on the CPU memory for Modbus FC3, FC16, and FC23.

The type 2 backplane path allows the Modbus message to be passed to the CPU. The NOE uses this path to pass all other function code requests to the CPU; the CPU handles the Modbus message. Function code examples include unlocated variables (FC42), PLC programming software (FC125, FC43), and read/write 0x, 1x, 3x requests. The type 2 path is not used to answer requests for 4x registers (FC3, FC16, and FC23).

The number of backplane paths limits the Modbus server performance. For example, if 10 FC3 and 5 FC42 Modbus requests are queued inside the NOE module, a total of 5 CPU scans is needed to compete the transfer. During the first 3 CPU scans, 10 FC3 (4 per CPU scan) and 3 FC42 (1 per CPU scan) requests are transferred, but an additional 2 CPU scans are needed to transfer the remaining 2 FC42 requests.

Unity Modbus Server Performance

In a Unity Modbus server system, path types and uses remain the same, but performance is improved 2 to 4 times over the Concept system.



The Unity 2.0 NOE/backplane supports:

- eight type 1 path requests served per CPU scan
- four type 2 path requests served per CPU scan (up to a limit of 20 requests)

Note: To see the improvement, you may need to adjust the SCADA package to make sure enough requests are being sent to the PLC.

Modbus Server Operations in Premium Systems

Premium Implementation

Premium PLC systems implement a Modbus server in the PLC's CPU. ETY cards or embedded ports pass Modbus requests to the CPU for processing. The CPU limits the number of Modbus requests that the server can answer per CPU scan. This limit includes requests from:

- Modbus TCP/IP
- Fipway
- Modbus serial
- Unitelway
- Ethway

A *Modbus busy* exception occurs when the CPU receives more requests than it can handle during a CPU scan. If this happens, an exception response is sent back to the Modbus client that sent the request.

The following table shows the number of requests processed per CPU scan for different Premium PLC systems.

PLC		**Ethernet Communications Mechanism**	**Responses per Scan**
Pre-Unity v2.0	Unity Pro v2.0 CoPro	ETY module* or embedded port**	20 (estimated)
	Unity level 2 P57-xx	ETY module*	20
	Unity level 4 TSX 574-xx	ETY module*	20
	PL7 level 2 TSX572-xx	ETY module*	8
	PL7 level 4 TSX574-xx	ETY module*	16
Unity Pro v2.0	Unity CoPro	embedded port**	16
		ETY module*	20
	Unity TSX P57304M	ETY module*	12
* The ETY module is limited to 400 transactions/s for all modules.			
** The embedded Ethernet port is limited to 500 transactions/s on the Unity CoPro systems.			

Premium Modbus Server Operation

The response process for Premium systems functions as follows:

Sequence	Event
1	The Modbus client establishes a TCP socket to the ETY module or embedded Ethernet port.
2	The Modbus client sends a request along the TCP socket.
3	The ETY module or embedded Ethernet port receives the request and may acknowledge it.
4	The request is placed in the ETY module/embedded Ethernet port queue.
5	At the beginning of the next CPU scan, the ETY module/embedded Ethernet port passes requests to the CPU. At this time, all communication modules pass requests to the CPU, including Fipway, Ethway, and SCP serial modules.
6	The CPU answers as many requests as possible (the limit is determined by the CPU).
7	If more requests are received than can be answered, the CPU responds with a Modbus busy exception to the ETY module/embedded Ethernet port, which sends the exception response back to the clients.
8	The ETY module/embedded Ethernet port receives responses to all answered requests and sends responses back to the clients.
9	The TCP socket is left open.

Premium Response Times

The Premium response time is the time period between receiving a request and starting the next CPU scan.

Modbus Server Operations in Momentum Systems

Momentum Implementation

The Momentum PLC implements a Modbus server as part of the main CPU. There is no limit on the number of Modbus requests that can be answered by a Momentum CPU.

Momentum Modbus Server Operation

The Modbus server for Momentum CPU operates as follows:

Sequence	Event
1	The Modbus client establishes a TCP socket to the Momentum CPU, which may take several CPU scans.
2	On the first scan, a SYN is received and is sent back to the client at the end of the scan.
3	The Modbus client sends a request along the TCP socket.
4	The CPU receives the request.
5	The request is answered at the end of the next CPU scan.

Modbus Servers and Socket Limits

Simple Modbus Servers

Product	Response Time
Advantys	4.5 ms
ATV58 Drive	30 ms
Momentum ENT1100/02	1 ms (additional 4.5 ms to include I/O base)
Momentum ENT1101	5-9 ms

Note: The response times above do not include I/O reaction times.

Modbus Server TCP Socket Limits

Product	TCP Socket Limit
Quantum NOE modules NOE77100/10	32
Quantum NOE modules NOE77101/11	64 (all Ethernet services combined)
Premium ETY410/510	32 (all Ethernet services combined)
Premium ETY4102/5102	64 (all Ethernet services combined)
Momentum CPU	12
Momentum ENT1100/02	4
Momentum ENT1101	4

Modbus Messaging Retry Times and Time-outs

Modbus Client

The Modbus client service supports retry times at the application layer (see *p. 125*). The system also performs TCP retries to make sure that Modbus requests and responses are being delivered. Modbus retry times and time-outs are device-dependent:

Platform	TCP Retry Times	Modbus Client Time-outs
Quantum	5, 25, and 45 s	30 s, no retries
Premium	5, 25, and 45 s	user-defined (in the communication block) with no retries

Modbus Server

The Modbus server service does not support retry times at the applications layer. The system implements TCP retries to make sure Modbus requests and responses are delivered. The retry times are device-dependent:

Platform	TCP Retry Times
Unity 2.0 Quantum	50 ms, 800 ms and 1.5 s
Unity 2.0 Premium	50 ms, 800 ms and 1.5 s
Quantum	800 ms and 1.5 s
Premium	800 ms and 1.5 s

3.4 Global Data Service

At a Glance

Overview

The global data service supports the transfer of real-time information from a source device to any other device on the network that subscribes to that information.

What's in this Section?

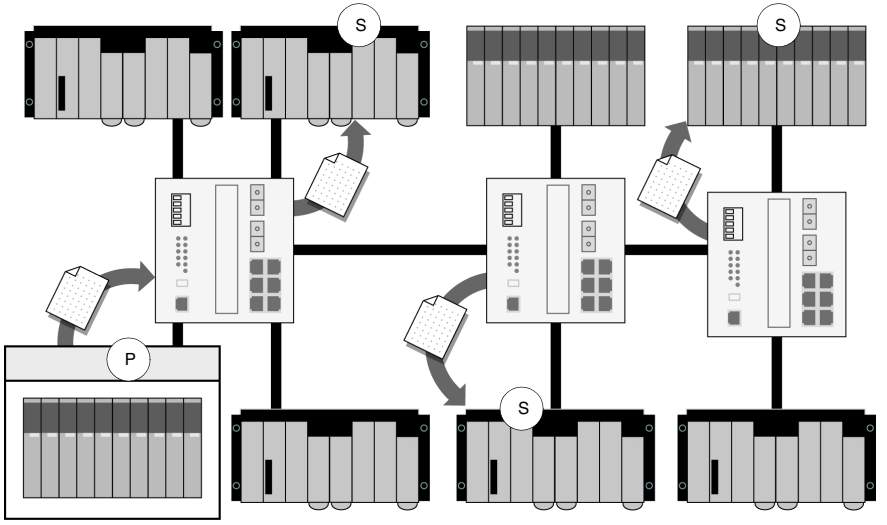
This section contains the following topics:

Topic	Page
The Global Data Service	198
Global Data Considerations	202

The Global Data Service

Summary

The global data service on Ethernet provides the ability for one device to *publish* real-time information to the network. Any device connected to the network can choose to receive this information. Devices that need to exchange information are arranged in distribution groups. Each device in a group can choose to publish a block of data to the entire group and can select blocks of published data that it wants to subscribe to (receive).



P publisher
S subscribers

Global Data Standards

The global data service is implemented using the standard network data distribution service (NDDS). NDDS uses the real-time publish subscribe (RTPS) protocol as defined by Real Time Innovations (RTI). This has been adopted as a standard by the Object Management group (OMG), the same group responsible for the COBRA standard. The global data service is responsible for the mechanics of distributing data over an IP network by using multicast technology.

The combination of the above services distributes the global data using UDP/IP multicasting technology.

Publisher and Subscriber Operations

The global data operation involves two types of participants with one or more publishers and one or more subscribers. A publisher is responsible for putting data on the network. The publisher takes a collection of local data and sends it to the distribution group at a rate configured in the publisher device.

The distribution group is a logic group of subscribing devices, possibly spanning across more than one network. You can make a subscribing device part of a distribution group by assigning it a unique multicast IP address. This IP address is a separate, additional IP address from the normal IP address used for Modbus, I/O scanner, Web, etc. All devices within the distribution group use this unique multicast IP address (see *p. 135*).

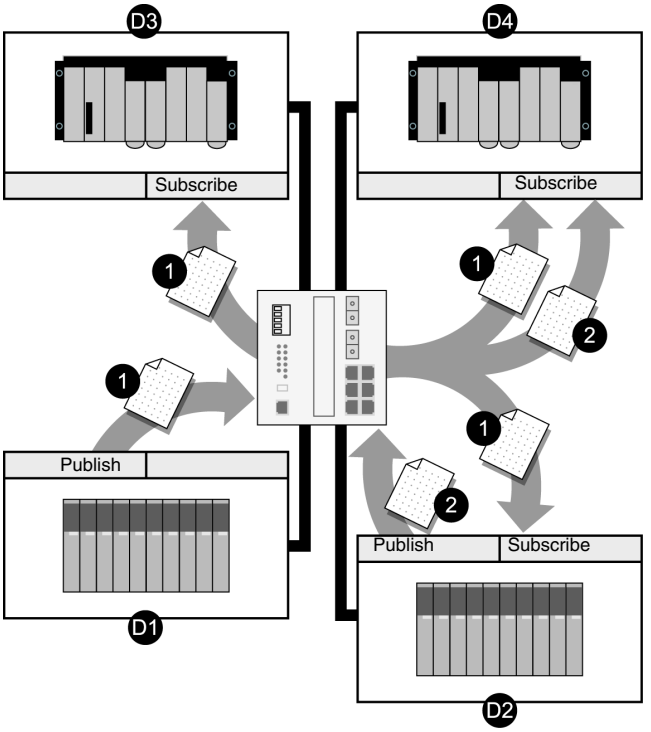
The subscriber receives a copy of all data published to the distribution group, selects only the blocks of data that it subscribes to, and passes that data to the user application.

Error handling must be done on the subscriber side because the publisher does not send the data to individual subscribers. The publisher puts data on the network; it has no control over the subscribers and does not receive feedback when a subscriber receives data. The subscriber is responsible for monitoring the time between receiving new data from each publisher. If the time between two successive updates of data from an individual publisher is longer than the configured health time-out, the service informs the user application on the subscriber device of an error. The subscriber must perform error monitoring and take action if the data is not received.

This is different from Modbus communications, where a command is sent to another device to perform an action. In the case of Modbus, the device sending the command must know if it is successful. With global data, the publisher just makes the information available and leaves it to the subscriber to receive and act on the information.

If for any reason a subscribing device does not receive a particular copy of newly published data to which it subscribes, the device receives an update of that data in the next publication cycle. The global data service publishes status information at a fast regular rate, and the next subsequent publication provides the current status of the subscription data, rather than a retry of the previous data.

The following figure shows a distribution group comprising four devices (D1 through D4). Two of these devices are publishers (D1 and D2) and three are subscribers (D2, D3 and D4). Device 2 is both a publisher and a subscriber. The data flow illustrates how devices 1, 2 and 3 all subscribe to data published by device 1 and device 4 subscribes to data published by both devices 1 and 2.



Limits

The global data service has the following communication limitations:

- A distribution group may contain up to 64 members; each device that is a member can be a publisher, subscriber or both.
- The current restriction is that each Ethernet module can be a member of only one group. Therefore, in order for a system to be a member of multiple groups, there must be multiple Ethernet communications modules in that system.
- A publisher can publish a single block of data up to 512 words long.
- A subscriber can receive any number of published data blocks from the group, although some PLCs restrict the total amount of data received by the service.

When to Use Global Data

Global data is used when a single device wants to make the information it contains available to multiple devices within 10 ms to 30 s. This service is used for publishing device data and plant status from one device to many others. Global data is not recommended for issuing commands, because the publisher does not send the data to an individual device and data transfer is not acknowledged.

The system is designed for a device to publish its status and for other devices to react to that status. For example, a drive publishes its speed and all other drives in the system adapt their speeds to match it.

Global Data Devices

The following devices implement global data with a maximum publishing of 512 words and a maximum subscription of 2048 words:

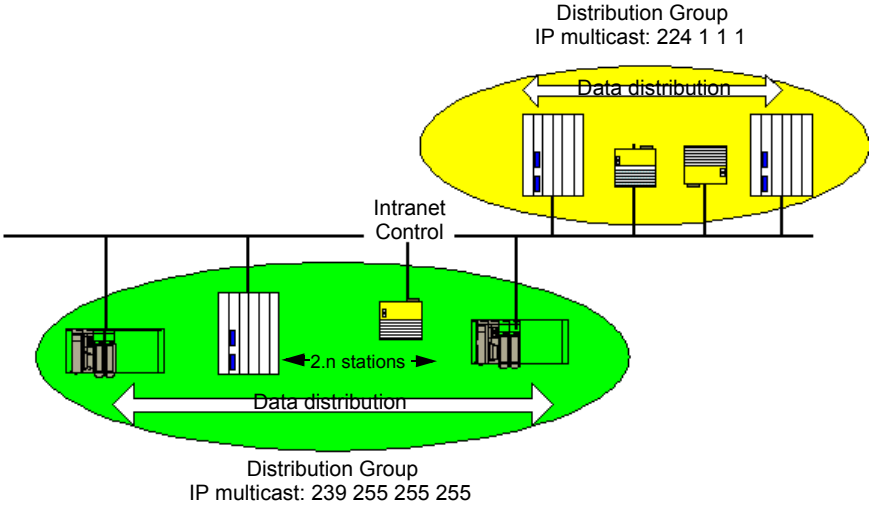
- ETY4102/5102 and ETY4013/5103
- Premium and Quantum CoPro Ethernet port
- NOE77101/11

Global Data Considerations

Multicast Technology

The global data service is implemented using multicast technology (see *p. 135*). Multicast is different from broadcast and unicast technologies. Broadcast sends information from one device to all devices on the network. Unicast sends data from one device to another. Multicast allows a device to send a single block (packet) of data to a predefined distribution group (see *p. 199*).

Published data that is sent to a specific multicast IP address is forwarded by switches and routers only to devices in the distribution group that subscribe to that multicast IP address. Multicast filtering (see *p. 136*) restricts the data from going to every device on the network and allows the distribution group to operate efficiently on an Ethernet network without disturbing other devices on the network.



The global data service currently implements GMRP to set up multicast filtering. GMRP is the protocol that the end device uses to notify switches and routers that it wants to receive data from a particular multicast IP address. That IP address belongs exclusively to a distribution group.

Application Synchronization

The publication of data is synchronized at the start of the CPU cycle after the configured publication rate has been reached. Subscribed data is recopied in the application memory of the subscribing device at the end of the CPU cycle after the data is received.

Response Time

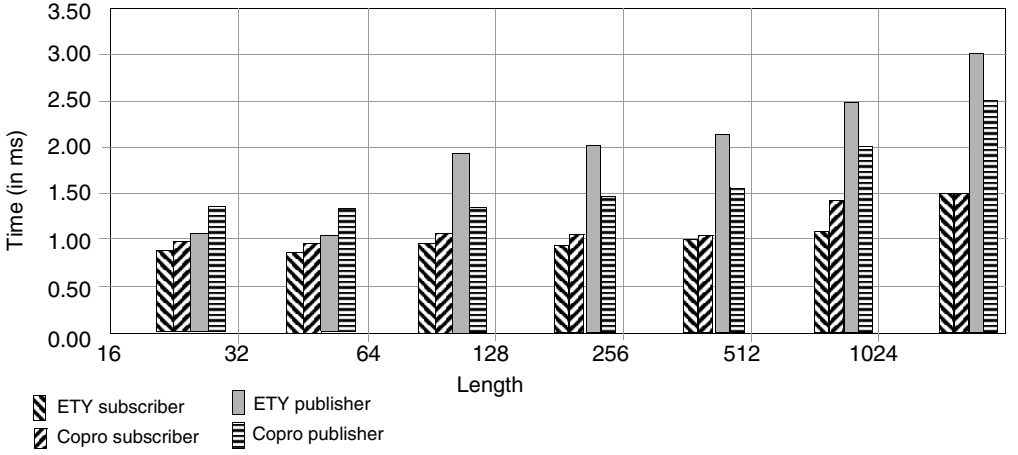
Global data response time is measured from a status change in the publisher to the time when the change is known in the subscriber:

publication time + 1 CPU scan on the publisher + publication time of the service + network time + subscription time of the subscriber + 1 CPU scan on the subscriber

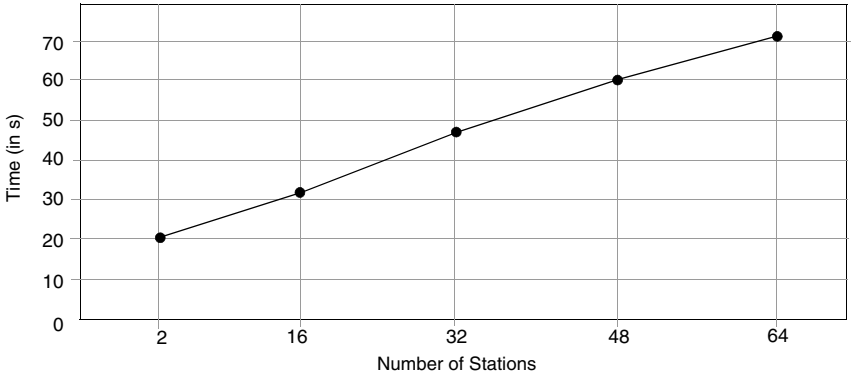
where *publication time of the service* and *subscription time of the subscriber* are generally 1 to 2 ms each.

Note: ETY systems need to include one additional CPU scan on the subscriber.

The following diagram shows system start-up times for a Premium ETY Ethernet communications module and a Unity Copro module. The response times for both devices are measured with each device used as a subscriber and as a publisher.



The following diagram shows the maximum time required to reach a steady state (measured in seconds).



3.5 Faulty Device Replacement

At a Glance

Overview

When the FDR service is supported in a field device, you can easily and reliably replace the device if it fails. When the replacement device is installed, it is automatically reconfigured with the operating parameters and IP address of the failed device.

What's in this Section?

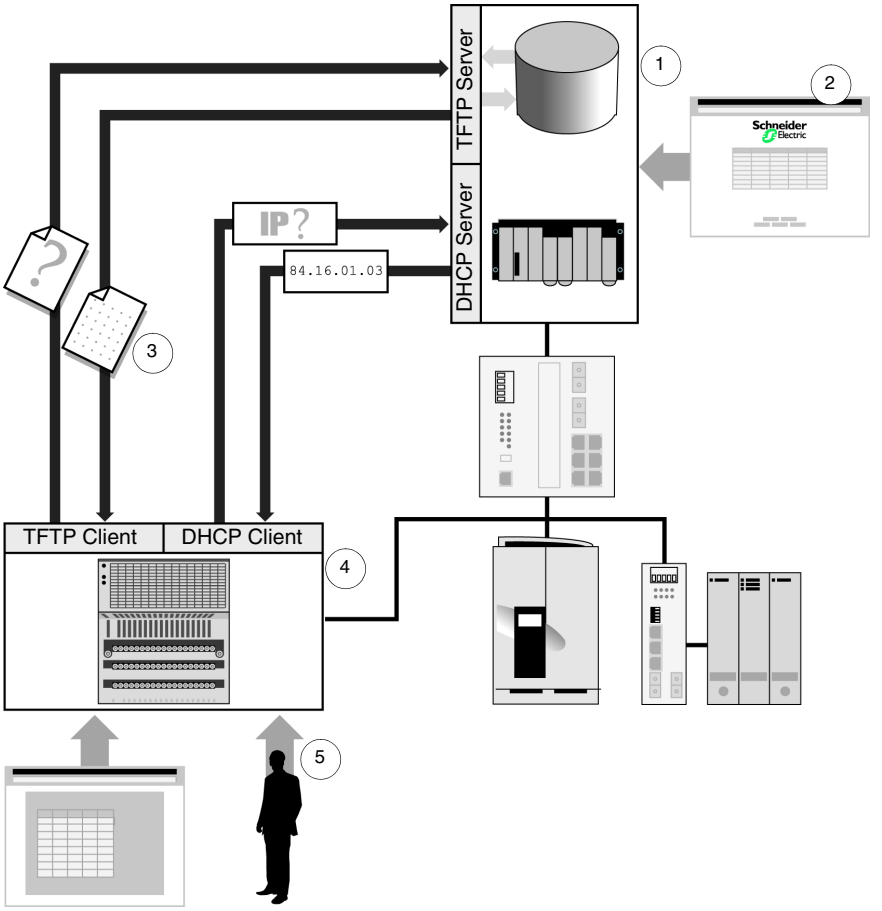
This section contains the following topics:

Topic	Page
Faulty Device Replacement	205
Devices that Support the FDR Services	207

Faulty Device Replacement

Summary

The FDR service uses a central FDR server to store network parameters and the operating parameters of devices on the network. If a device fails, the server automatically configures the replacement device with the identical parameters as the failed device. The FDR service removes the need for service personnel to keep configuration records on hand and reduces the possibility of human error in entering the new configuration.



1 FDR server
2 server configuration
3 operating parameter file transferred to the FDR client
4 FDR client (replacement device)
5 rolename assignment

FDR Components

An FDR service comprises an FDR server and a client. The server is a passive device; it simply stores all the parameters for the devices on the network. To configure the server, create a list of the devices connected to the network (each identified by a *rolename*) and their IP parameters. After the FDR service is enabled, the server responds to requests from the FDR clients.

The FDR client is a network device that stores its parameters on the FDR server to facilitate replacement of the device. Each client is assigned a rolename that uniquely identifies it from other devices on the network. After the device is connected to the network, it sends a copy of its operating parameters to the server. The actual parameters depend on the type FDR client device, but they should always be sufficient to enable a replacement device to be configured to operate exactly as the original client. After the server has a copy of the parameters, the client periodically checks to see that the server has a current set of parameters. An update is sent to the server when there is a change in the client's operating parameters. Depending on the client's implementation, this update may or may not be automatic.

If a client fails, the following occurs:

Sequence	Event
1	Your service personnel must assign the same rolename to the replacement device.
2	Your service personnel places the new device on the network.
3	The device automatically issues a request to the server for a set of IP parameters that is used by a device with this rolename.
4	The device receives the IP parameters and then connects to the FDR server and downloads a copy of its operating parameters.
5	After the parameters are downloaded, the device implements the parameters and operation resumes.

The actual parameters may include a device consistency check to see that the replacement device is of the same type as the original. Based on this check, the client may choose to operate even if the replacement device is different from, but still compatible with, the original device.

When to Use FDR

FDR should be used for all devices that support this service on an automation network. As Schneider Electric adds FDR support into more of its devices, plants should be updated. At the present time, the service focuses on I/O devices, not on PLC or HMI systems. In Hot Standby system, you are unable to use the FDR server. Only one FDR server is permitted on a subnet (see *p. 132*). If you reach the limit for FDR clients on a network, split the network and assign a new FDR server to the newly established network.

Devices that Support the FDR Services

Device		FDR Client	FDR Server
Quantum	140CPU65150	-	X
	140CPU65160	-	X
	140NOE77101	-	X
	140NOE77111	-	X
Premium	TSXP571634M	-	X
	TSXP572634M	-	X
	TSXP573634M	-	X
	TSXP574634M	-	X
	TSXP575634M	-	X
	TSXETY4103	-	X
	TSXETY5103	-	X
TSX Micro	TSXETZ410	X	-
	TSXETZ510	X	-
Momentum	171ENT11001	X	-
Advantys STB	STBNIP2212	X	-
Altivar ATV38/58	VW3A58310	X	-

3.6 Time Synchronization

At a Glance

Overview

This section describes the time synchronization service and how it distributes time to devices on the network.

What's in this Section?

This section contains the following topics:

Topic	Page
Time Synchronization Service	209
Time Synchronization Service Operation	211
Time Synchronization Applications	212
Schneider Devices Implementing Time Synchronization Service	216

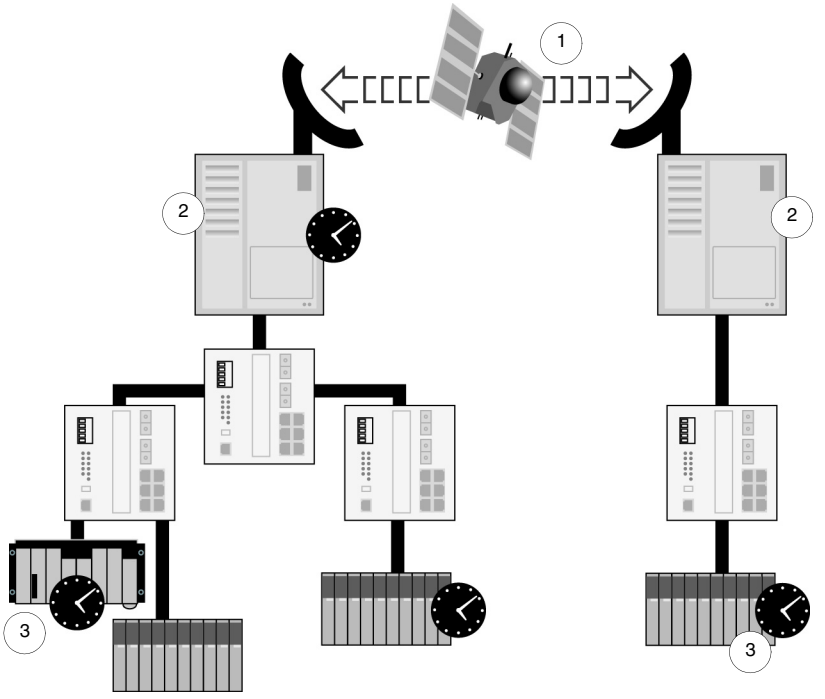
Time Synchronization Service

Time Synchronization Summary

Time synchronization is a service that distributes and maintains an accurate time for devices on the network. Typically, the time is accurate to within 1 to 2 ms. After the devices have been time-synchronized, this service can be used to:

- synchronize an action
- time-stamp the occurrence of events (sequence-of-events recording)
- manage the order of plant operations

Time synchronization is achieved by sending out periodic time updates to all the devices configured for this service.



1 GPS satellite time
2 NTP time servers
3 local time

Time Synchronization Description

Time synchronization uses SNTP to distribute the server time to all clients that implement this service. The central time server may run independently or be connected to a GPS receiver, a DCF receiver, or a remote clock (using NTP). The NTP service operates in Greenwich mean time and local time zones and is administered by the clients. Several time servers can operate on the network to provide redundancy in case the primary server goes out of service.

To maintain accurate time, clients request the time from the server at configured intervals. Clients may make adjustments for network delays in the time transfer. Once the client receives the time, an internal clock keeps track locally. At the next configured update, the client requests the time from the server and synchronizes its local clock. The client's time accuracy is affected by the accuracy of the local clock, the update period, and the accuracy of the time server.

Many devices can be used as a time server (e.g., a Windows or Linux PC with a 1 to 30-ms accuracy, a dedicated time server with better than 1 ms accuracy). The time server maintains its time by using a local clock while receiving updates from a remote source like a GPS or a DCF receiver.

During time synchronization, all the clients request the time from the time server. Each client's internal clock is synchronized with the time server time, allowing all alarms and file-and-program-change time stamps across the plant to be recorded using the same time source. Time synchronization allows you to track the order of changes in the plant without the need to manually set the time in each device.

Sequence-of-events Recording

Sequence-of-events recording allows the order of events across a plant or across multiple plants to be reconstructed or examined very accurately. This application is based on the accurate time-stamping of events at their source.

Action Synchronization

Action synchronization allows multiple devices across a plant to execute an operation at the same time. It can be useful for starting drives along a conveyor or transferring products from one part of the plant to another.

Time Synchronization Service Operation

Detailed Service Operation

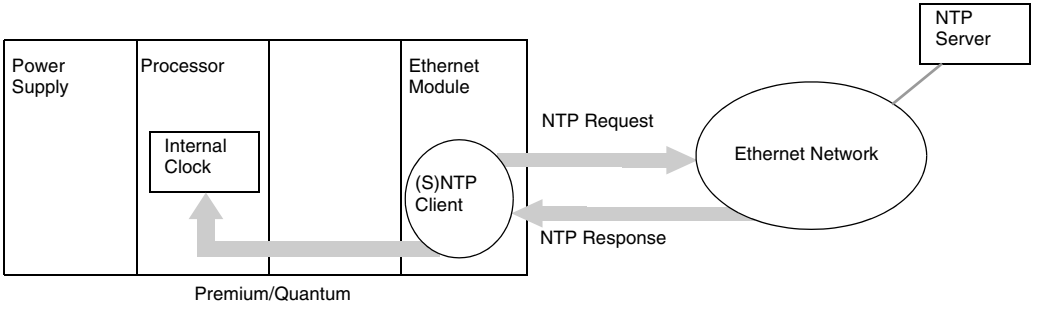
The time synchronization service uses SNTP to distribute the time from the central server to all clients who request it at configured intervals. By time-stamping the requests and responses at each point in the exchange, the clients can account for delays caused by the network. Network loads and delays generally do not affect the time signal accuracy. However, the delay is assumed to be uniform, so a delay that occurs on the request packet, but not on the received packet, may cause the client time to be inaccurate by a small amount.

After the client receives the time, its internal clock keeps time locally. At the next configured update, the client requests the time from the server and synchronizes its local clock again. The client's time accuracy is affected by the accuracy of its local clock and the update period. More frequent time updates result in less time drift and therefore more accurate client time.

Service accuracy is also determined by the accuracy of the time server. A time server can be from a Windows or a Linux PC to a dedicated time server with an atomic clock. The time server maintains its time by using its local clock while receiving updates from a remote source like a GPS or a DCF receiver. The internal clock's accuracy and the response time to NTP requests can affect the overall system accuracy. A Windows PC acting as an NTP server typically restricts the system accuracy to ~ +/-30 ms; a dedicated NTP server with a GPS receiver is accurate to within less than 1 ms.

This service is better than earlier time synchronization systems because it requires only a single connection. Earlier systems required each device to have a GPS or a DCF receiver, resulting in higher costs and difficulty in placing antennas.

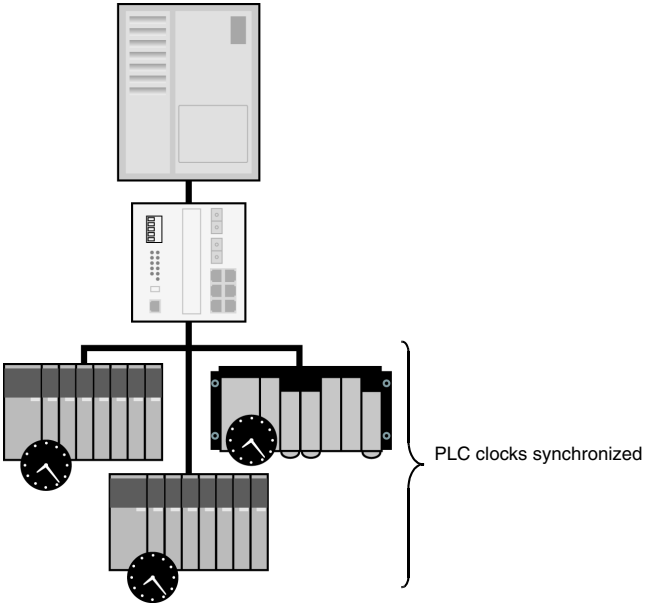
When a CPU acting as a client requests a time update, the Ethernet module obtains this information from the server and updates the CPU's internal clock. This internal clock now functions as the local clock for the PLC until the next time update. This clock can be accessed at any time inside the user logic by using a specific elementary function block.



Time Synchronization Applications

Functions that Use Time Synchronization

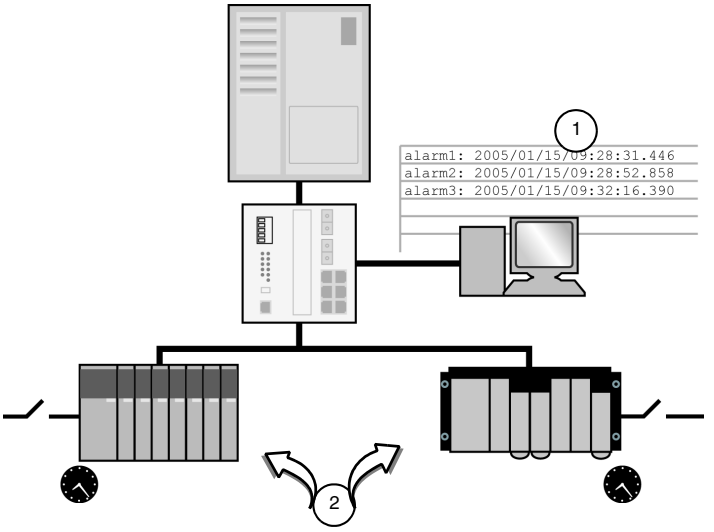
Time synchronization gives all devices on the network the identical time reference. This service supports event time-stamping, alarms, and program or file changes across the plant, based on the same time.



Sequence-of-events Recording

To time-stamp events, the PLC must be able to detect an event as it occurs at the I/O module. To do this, choose a module with minimal filtering and delay times. If possible, link the input module to an event task in the CPU (a feature supported on higher-end CPUs). The field event is detected by the module and calls the event task, interrupting the program and allowing the application code to time-stamp the input.

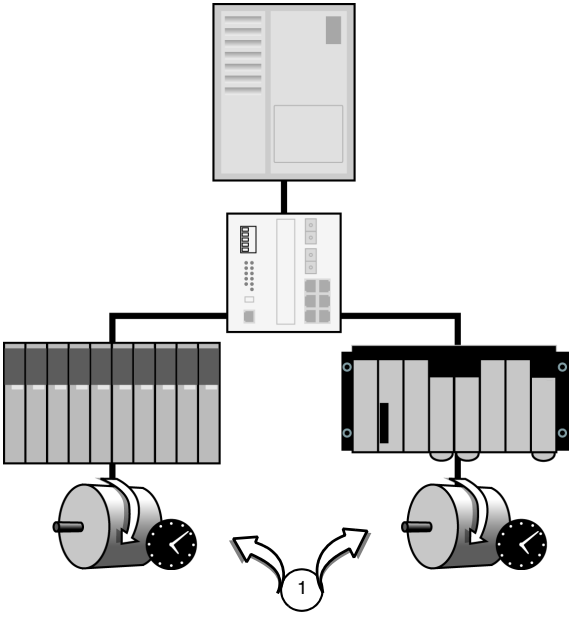
If the CPU does not support the implementation of event tasks, the *fast task* should be used. Configure the fast task to execute as frequently as possible. Unlike the event task, the fast task interrupts the execution of the main program to check for events. Fast task execution frequency should be configured so it does not heavily impact the execution time of the main program. The I/O module that contains the input event should be linked to the fast task; the fast task's first actions should be to check the I/O module for the input and to time-stamp that input if it represents a recordable event.



1 comparison of event times across the plant to determine the order of events
2 local time-stamping of events

Action Synchronization

The time synchronization service can synchronize the activation of events across one or more plants. Use the fast task to make sure that the current time is set equal to the time at which the event is configured to occur. If the time is correct, then the output should be activated. Accuracy is affected by the frequency of the fast task, the length of execution of the fast task (since the output is not activated until the fast task has completed), and the I/O activation time. The I/O module containing the event output must be linked to the fast task.



1 synchronized actions across the plant

Comparison with Traditional Event Recording Systems

The main differences between the time synchronization service and a traditional recorder system for sequence-of-events recording are cost and accuracy. A traditional implementation has an accuracy of 1 ms, but comes at a higher cost than a PLC system implementing the time synchronization service.

Any difference in accuracy is due to the I/O modules used. A traditional sequence-of-event recording system uses dedicated I/O modules with special filtering systems. The I/O module time-stamps the input as soon as it occurs and then begins to filter it. If the input is determined to be noisy, the event is discarded from the records.

The time synchronization service is based on normal PLC I/O modules where the input is filtered inside the module before it is passed to the CPU as an event and recorded by a time-stamp. This filter-before-recording method results in less accuracy, but it reduces costs because no special I/O modules are required.

The cost advantage is based on the distribution of the time across an existing Ethernet network. In a traditional system, a GPS or DCF receiver must be connected directly to each I/O module. The cost of multiple receivers and the difficulty of running antennas for these devices outside the plant (because GPS receivers require a clear view of the sky) is much greater than the cost of a single receiver attached to a central NTP time server. The Ethernet configuration requires only a single outside antenna system and uses the plant's existing Ethernet network.

Schneider Devices Implementing Time Synchronization Service

The TSXETY5103 and 140NOE77111 modules are the only Ethernet modules that support NTP protocol. The following table shows that the clock synchronization (resolution) differs depending upon which CPU you use with these two Ethernet modules.

Unity Module and Processor Used		**Predicted Typical Time Service Operation**		
Ethernet Modules	Ethernet Modules with Unity Processor	Clock Synchronization[1]	Event Synchronization	Time Stamping[2]
TSXETY5103*	TSXP570244M TSXP571x4M TSXP572x4M TSXP573x4M	+/-1 ms typical +/-10 ms maximum	= clock synchronization precision + fast task time + I/O time	= clock synchronization precision + I/O time
	TSXP574x4M TSXP575x4M	+/-1 ms typical +/-5 ms maximum		
140NOE 77111**	140CPU31110 140CPU43412U 140CPU53414U	+/-1 ms typical +/-10 ms maximum		
	140CPU65150 140CPU65160 140CPU67160	+/-1 ms typical +/-5 ms maximum		
[1] Time difference between field input and central server.				
[2] Assuming input connected to the interrupt module.				
* TSXETY5103 modules must be v3.1 or greater, and they are compatible with Unity 2.0 or greater.				
** 140NOE77111 modules must be v3.5 or greater, and they are compatible with Unity 2.0 or greater.				

3.7 Electronic Mail Notification Service

At a Glance

Overview

This section describes the electronic mail notification service and how it provides users with process data, production reports, alarms and event notifications.

What's in this Section?

This section contains the following topics:

Topic	Page
Electronic Mail Notification Service	218
Electronic Mail Notification Service Operation	220
Devices that Support Email Notification	222

Electronic Mail Notification Service

Summary

The electronic mail notification service allows PLC applications to report conditions monitored by the PLC by running an email client inside an Ethernet communication module. The PLC can automatically and dynamically create short electronic mail messages to alert specified users to:

- alarms
- events
- production reports
- maintenance reminders
- plant status updates
- other plant information

Recipients may be local or remote.

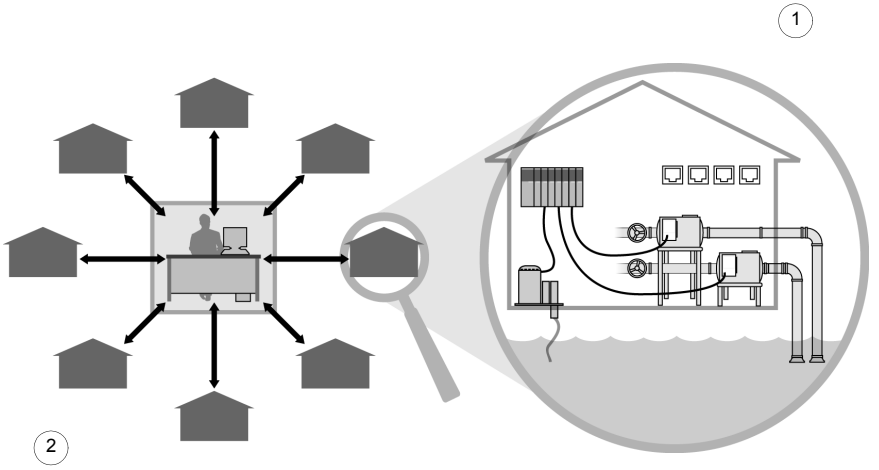
This service allows you to create predefined email headers (including recipients' names, email addresses, and message subject) to be used with different email bodies. Some devices let you include values dynamically obtained from the latest information in the PLC application or machine state; other devices allow only predefined messages. Multiple email messages can be created to describe different events or alarms, including several system variables. This option can be change by an authorized administrator.

Note: Because messages need to be processed through an email system, delays may occur between the time the message is sent and the time it is received. Therefore, this service should be used only for noncritical notification.

An Application Example

Many industrial facilities are connected to numerous pump houses in remote locations that supply them with water. These locations contain pumps, valves, and filters that require regular preventive maintenance based on the number of hours of operation. Maintenance dates may change from month to month depending on the utilization of the pumps, filters, or valves. Email notification to the maintenance crew when those maintenance limits are reached eliminates the need to travel to a remote pump house to check.

For example, one of the pump filters has been in service for 1000 hours over a period of 3 months without being cleaned or replaced and now requires preventive maintenance. Because the system has been configured to trigger a maintenance request after every 1000 hours of operation, an alarm is sent out by the Ethernet module to the email server to notify the maintenance crew to clean or replace the filter in the pump house. After the email server has processed the message and sent it to the company network, the maintenance crew receives the email notification. If the email server is set up to send messages to pagers or mobile phones, an additional notification could be sent to the maintenance crew using these media.

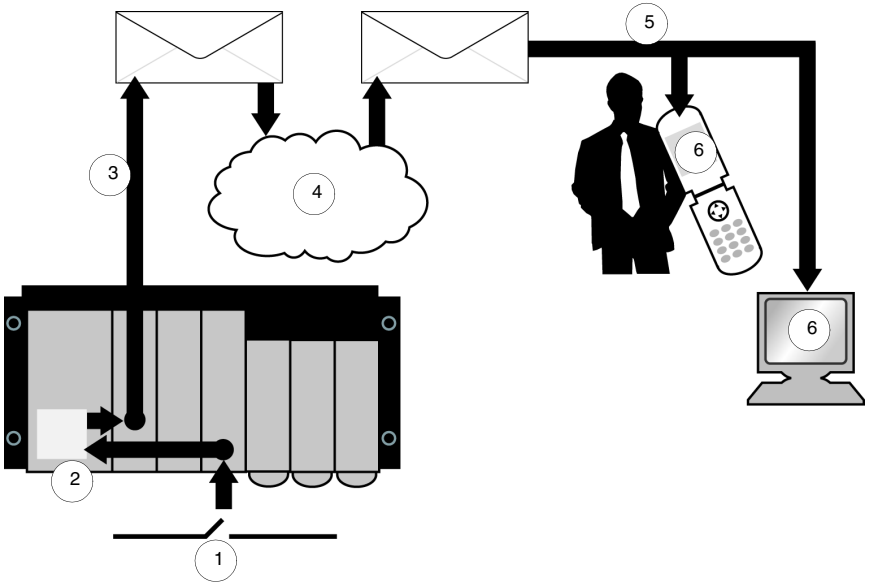


1 Email notification sent regarding pump run hours
2 multiple site report maintenance to contractor via email.

Electronic Mail Notification Service Operation

Service Operation

The electronic mail notification service is implemented inside an Ethernet communication module that serves as an email client. When a preconfigured event or alarm is triggered in the controller, the Ethernet module uses SMTP (over TCP port number 25) to communicate with an email server. That server is connected to the plant's network or to the Internet, thereby allowing the email message to reach its recipients. Email or SMS (short message service) messages may also be sent to mobile phones if the client's email server has the capability.



1 input event
2 email triggered
3 email sent to the mail server
4 Internet or email system
5 local mail server
6 email message displayed

Even though notifications are sent automatically after an event or alarm is triggered, there may be a significant delay before the recipient gets the message. The message is processed by an email server, sent through the Internet or company mail system, processed again by an email delivery server, then accessed by the recipient through his/her email account. A notification sent to a mobile phone is received only when the phone is on and within the coverage area. Therefore, this service should only be used for noncritical notifications, such as maintenance reminders or production reports.

Security

An optional login password, which is authenticated by the SMTP mail server to verify if the client is authorized to send emails, can protect each email message. To establish password protection, you can use a subset of the SMTP service extension for authentication (RFC 2554). This extension allows the client to authenticate prior to sending messages. Also, the SASL (a method for adding authentication support to connection-based protocols) includes a command for identifying and authenticating a user to a server and for optionally negotiating protection of subsequent protocol interactions. As a result of this negotiation, a security layer is inserted between the protocol and the connection. When enabled, both the login and the password are encrypted. To provide additional security, the site's email installation can change the TCP port number from the default setting of 25.

Additional Service Requirements

The notification service only provides an email client in the Ethernet module. The client sends electronic mail notifications. To enable recipients to receive these messages, the site where the Ethernet module is installed must have an email server, such as Lotus Notes, Microsoft Exchange, or Linux SendMail.The client connects to the email server to distribute the mail to its recipients.

Devices that Support Email Notification

Device		Security Feature	Maximum Number of Headers	Variables in Message Body	Dynamic Email Body Content
Premium	TSXP571634M (v3.1 or higher)	X	3	X	X
	TSXP572634M (v3.1 or higher)	X	3	X	X
	TSXP573634M (v3.1 or higher)	X	3	X	X
	TSXP574634M (v2.0 or higher)	X	3	X	X
	TSXP575634M (v2.0 or higher)	X	3	X	X
	TSXETY4103 (v3.1 or higher)	X	3	X	X
	TSXETY5103 (v3.1 or higher)	X	3	X	X
	TSXWMY100	-	100	X	-
Quantum	140CPU65150 (v2.0 or higher)	X	3	X	X
	140CPU65160 (v2.0 or higher)	X	3	X	X
	140NOE77101 (v3.5 or higher)	X	3	X	X
	140NOE77111 (v3.5 or higher)	X	3	X	X
	140NWM10000	-	100	X	-

3.8 Standard Web Server

At a Glance

Overview

The section describes a service that uses a standard Web browser to diagnose and configure Transparent Ready devices.

What's in this Section?

This section contains the following topics:

Topic	Page
Web Server Services	224
Web Server Operation	226
Devices that Support Standard Web Server Services	229

Web Server Services

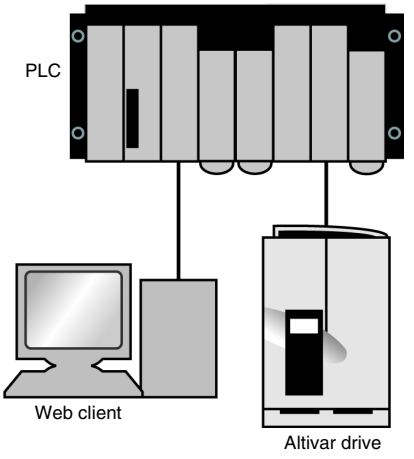
Summary

Embedded diagnostics are used to execute diagnostic and maintenance functions. They can be run either locally or remotely through a simple Internet browser. This service uses an embedded Web server and a real-time data server. All data is presented in HTML format and can be accessed from any Internet browser. This service is a convenient way to monitor the health of devices on the network and to access operational and configuration information.

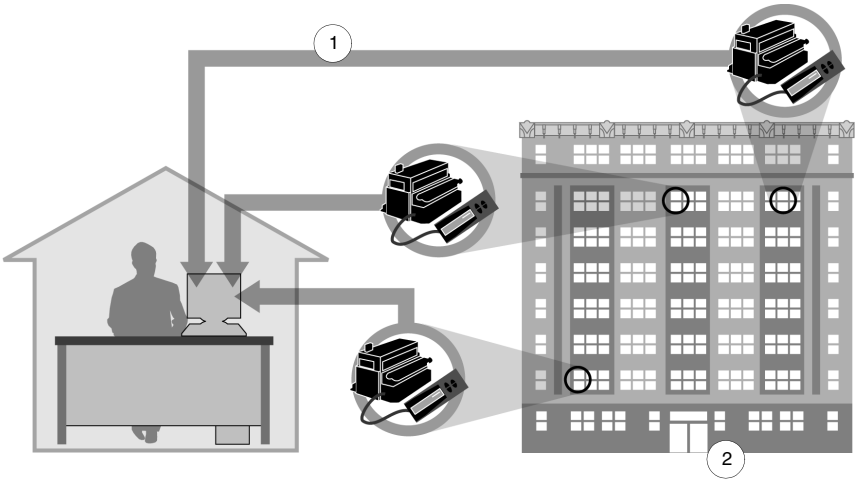
The embedded Web server is a real-time PLC data server. All the device, diagnostic, and configuration data is viewed in HTML by using any Internet browser with a Java virtual machine (JVM) to support the integrated Java code. No programming is required at either the Transparent Ready device level or at the PC running the Web browser.

Web Service and Web Pages

Some automation devices allow remote configuration via Web pages. For example, Altivar drives provide access to current speed information and allow you to configure acceleration rates through the Altivar drive's Web pages. The Web client can then access the Altivar drive's Web pages.



Another application is monitoring power usage in apartment buildings. If Power Logic circuit monitors are installed at various circuit breakers throughout the building, an administrator can remotely monitor the power usage of each tenant simply by accessing the Power Logic circuit monitor's Web page with a Web browser. Eliminating the need to physically read each meter saves a vast amount of time and resources.



1 remote access to the power meters over the building's Ethernet network
2 office building configured for separate power metering for each tenant

Web Server Operation

Summary

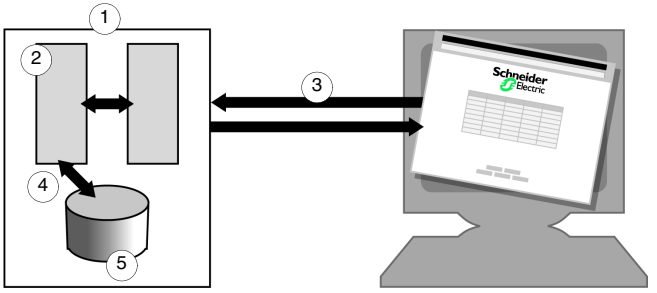
When an HTTP client accesses the Web server, the application receives the request and retrieves the required data from the device's memory. The information is sent back to the client in the form of a Web page. The Web server is a passive service; it runs only when information is requested from it. The Web pages are in HTML format; they are stored on the Web server along with other data source files such PDF, JPG, etc. Some Web servers can display real-time data, but a JVM must be installed to enable the client to display these Web pages.

When you try to access a Web page, the Web browser issues a request to the server. After the server handles the request, it sends the HTML pages back to the client. There are two types of Web pages:

- static pages, which may or may not contain real-time data. If you want to refresh real-time data, the Web pages must be reloaded, which means another request must be sent.
- dynamic pages, which do contain real-time data. These Web pages contain Java applets that run on the client's JVM, retrieve real-time data from the Web server, and display data in the Web browser.

With static pages, such as those from an EGX Gateway or an NOE configuration screen, the client needs to a refresh the page request to update the data. The Web server accesses the HTML page, obtains the real-time data, updates the HTML file, and then sends the information back to the destination. The client can request updates as needed.

With dynamic pages, such as Ethernet statistics on a NOE module, the data updates are provided by Java applets. The client requesting the data must have a JVM running. When you access HTML files, the static portion of the HTML file is downloaded along with the Java applets. The Java applets running inside the JVM on the client issue a Modbus request for the device to obtain the real-time data.



1 an http server
2 a Web page
3 request for a Web page
4 current dynamic data values placed into the Web page
5 device memory

Common Web Pages

The more common Web pages are:

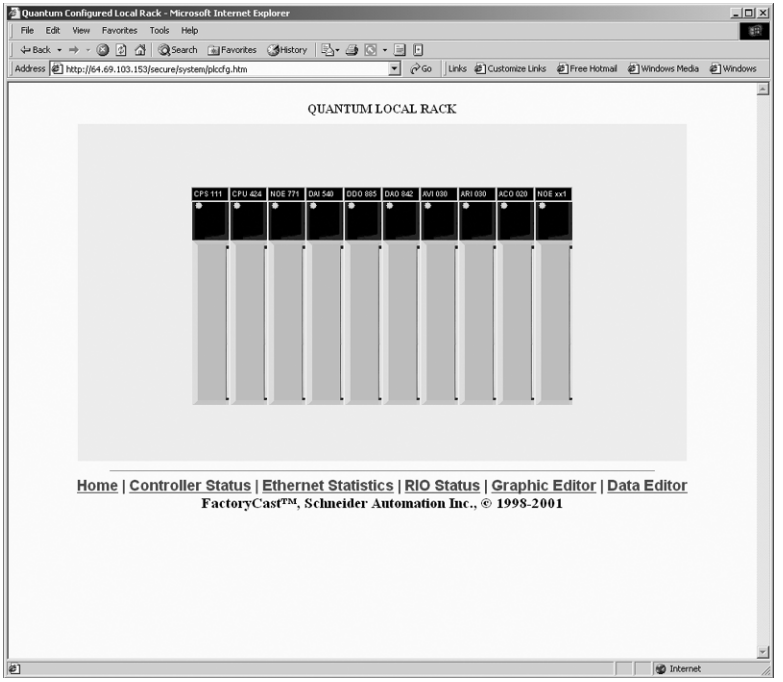
- rack viewers
- data editors
- Ethernet statistics displays
- device property displays
- menus
- device configuration screens
- device diagnostics displays

Rack Viewers

A rack viewer is supported in Ethernet TCP/IP modules for the following platforms and devices:

- TSX Micro
- Premium
- Quantum
- Momentum
- Advantys STB
- FactoryCast

A typical rack viewer Web page looks like this:

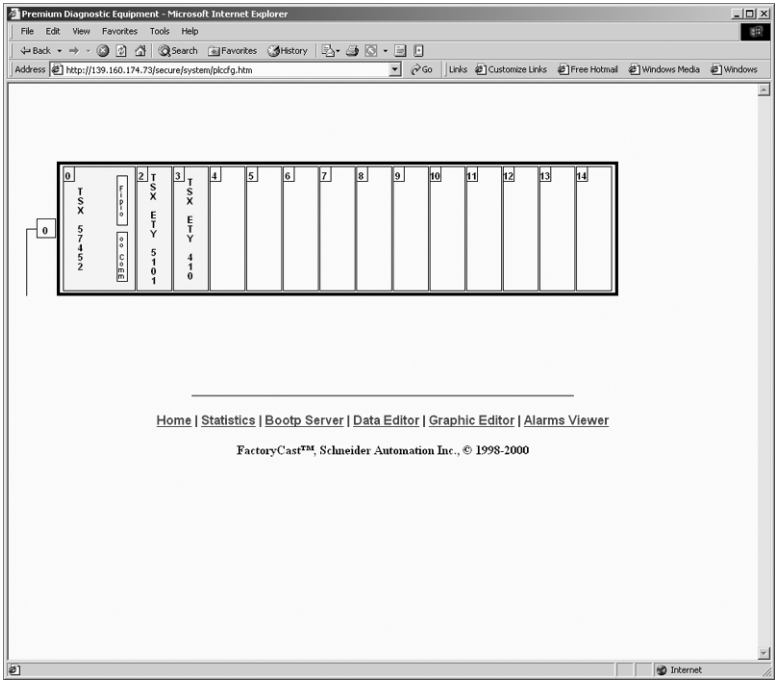


Data Editors

The data editor function can be used to create tables of animated variables for real-time read/write access to lists of PLC data. The variables to be displayed can be entered and displayed symbolically (S_Pump 234) or by their address (*%MW99*).

These variables support write access only if this option has been enabled using FactoryCast configuration software. A second password must be entered and verified when writing a value to a variable. You can create various animation tables containing specific application variables to be monitored or modified and save them in the Ethernet TCP/IP module.

The following illustration shows a data editor:


Premium Diagnostic Equipment - Microsoft Internet Explorer
File Edit View Favorites Tools Help
Back Search Favorites History
Address http://139.160.174.73/secure/system/plccfg.htm
Go Links Customize Links Free Hotmail Windows Media Windows
TSX 57 452
TSX ETY 5101
TSX ETY 410
Home | Statistics | Bootp Server | Data Editor | Graphic Editor | Alarms Viewer
FactoryCast™, Schneider Automation Inc., © 1998-2000
Internet

Ethernet statistics: Ethernet statistics include IP parameters, the number of packets transmitted and received, and any errors at the Ethernet layer.

Device properties: Device properties display the current product version, the operating system, and the firmware or kernel version.

Menu: Menus display lists of pages available from a device.

Device configuration: The device configuration shows the service configurations on the device.

Device diagnostics: Device diagnostics are the diagnostics of the services on that device.

Devices that Support Standard Web Server Services

Product		Reference
Quantum	Processor	140CPU65150
		140CPU65160
	Modules	140NOE771001
		140NOE 77111
		140NWM10000
Premium	Processor	TSXP572623M
		TSXP572823M
		TSXP573623M
		TSXP574823M
		TSXP571634M
		TSXP572634M
		TSXP573634M
		TSXP574634M
		TSXP575634M
	Module	TSXETZ4103
		TSXETY110WS
		TSXETY5103
		TSXWMY100
TSX Micro	Modules	TSXETZ410
		TSXETZ510
Momentum	M1E processors	171CCC96020
		171CCC96030
		171 CCC 980 20
		171 CCC 980 30
	Modules	170 ENT 110 01
		170 ENT 110 02
Advantys STB		STBNIP2212
Altivar ATV 38/58		VW3 A58310
Power Logic Gateway		EGX200
		EGX400

3.9 FactoryCast Web Server

At a Glance

Overview

The section describes how to use the FactoryCast Web server to control and monitor plant operations.

What's in this Section?

This section contains the following topics:

Topic	Page
FactoryCast Web Server	231
FactoryCast Web Server Operation	233
Devices that Support FactoryCast Web Server Services	235

FactoryCast Web Server

Summary

A FactoryCast Web server is an extension of the standard Web server that provides plant diagnostics and control through customized Web pages. The following functions are available:

- management of device and plant alarms with partial or global acknowledgment (ready-to-use pages for the alarm viewer function)
- graphical plant diagnostics (customized user-generated graphical views using the graphic data editor function)
- graphical plant control via user-generated animated Web pages that are stored in the FactoryCast module

The customized Web pages are transferred to the module using FactoryCast configuration software.

Hosting and Displaying User Web Pages

FactoryCast Web modules have a memory area that hosts user-generated Web pages. These Web pages may be created with standard HTML editing tools such as Microsoft FrontPage and Macromedia Dreamweaver. Java applets linked to PLC variables can enhance these pages by providing graphical representations of plant status. These animated objects are provided in the graphic data editor supplied with FactoryCast.

The Web pages can be used to:

- display and modify variables in real time
- create hyperlinks to other external Web servers

The graphic data editor lets you create graphical screens for:

- display, monitoring, and diagnostics
- generation of real-time production reports
- maintenance manuals
- operator guides

Configuration Software for FactoryCast Web Servers

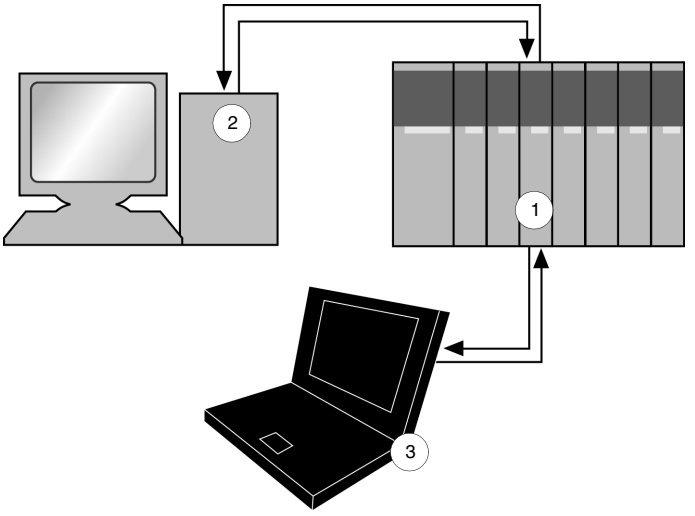
The MS Windows-based configuration software for FactoryCast Web servers is supplied on CD-ROM with every FactoryCast module. Use the software to configure and administer the Web server embedded in these modules. It allows you to:

- access security management
- define user names and passwords for accessing Web pages
- define access to variables authorized for modification
- save/restore an entire Website
- transfer Web pages created locally to and from the FactoryCast module

FactoryCast Web Server Uses

Your ability to configure plant diagnostics makes important information readily available and lays it out in a format you choose. You can create Web pages that contain manuals, operating procedures, and useful reference material such as CAD drawings.

If the files become too large, you can store them on separate Web servers and store only the links to those files on the FactoryCast device. The illustration shows how a FactoryCast web server accesses documents:



1 a FactoryCast module where links to a central Web server are stored
2 the central Web server where documents are stored
3 a Web client can access the desired documents through the FactoryCast module

FactoryCast Web Server Operation

Alarm Viewer

The alarm viewer is a ready-to-use alarming system comprising a password-protected alarm page (viewable in a Web browser) and function blocks inside the device (used to add alarms to the alarm system). The diagnostics buffer in the device is the source of the alarms on the Web page. This system can be used:

- to process device alarms (display, acknowledgment, and deletion) that can be managed automatically by the system
- by the user application employing diagnostic elementary function blocks (EFBs)

The alarm viewer is a Web page that contains the following information for each alarm:

- its state
- the type of associated EFB
- its geographical area
- the dates and times of the occurrence/removal of a fault

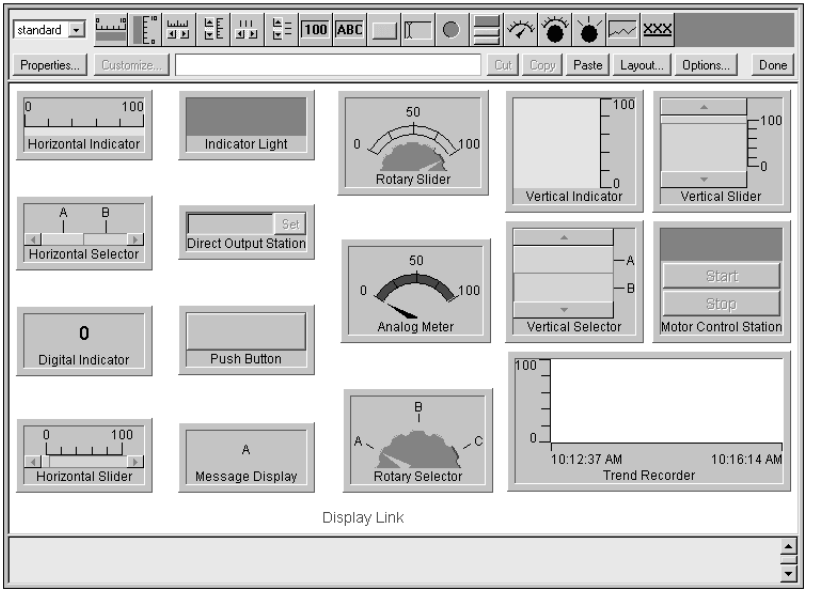
Graphic Data Editor

The graphical data editor can be used to create customized screens showing animated plant data. These views are created in a Web-based tool (accessed from the FactoryCast device) using a library of graphic objects. The objects may be customized for color, PLC variables to display, labels, etc. The following graphic objects are provided:

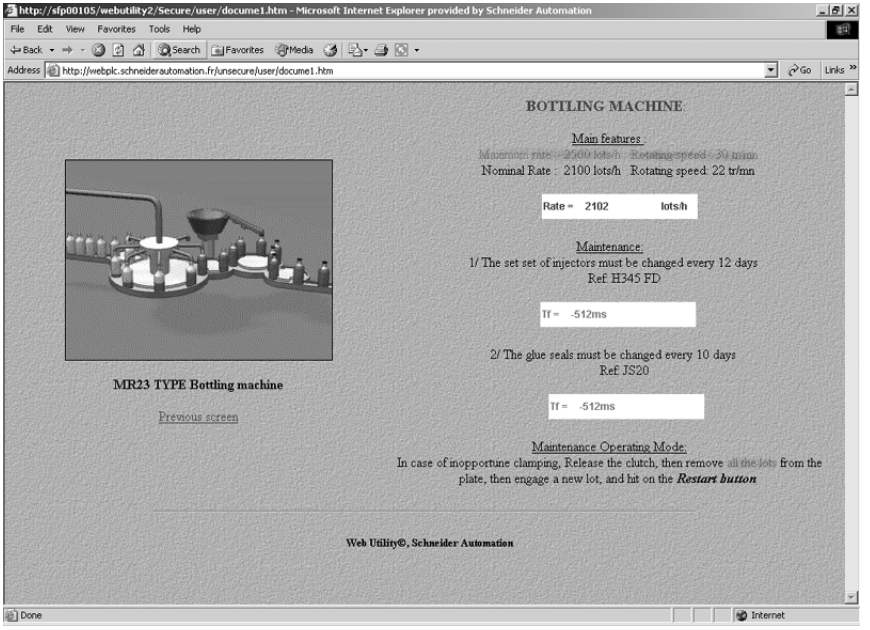
- analog and digital indicators
- horizontal and vertical bar charts
- boxes for displaying messages and entering values
- push button boxes
- functions for displaying trends

After the screens are created, they can be stored in the FactoryCast device for future use or to be reused in customized Web pages.

The following illustration shows some of the objects that can be used to develop a graphical screen:



A completed graphical screen might look something like this:


http://sfp00105/webutility2/Secure/user/docume1.htm - Microsoft Internet Explorer provided by Schneider Automation
BOTTLING MACHINE
Main features :
Nominal Rate : 2100 lots/h Rotating speed 22 tr/mn
Rate = 2102 lots/h
Maintenance:
1/ The set set of injectors must be changed every 12 days
Ref. H345 FD
Tf = -512ms
2/ The glue seals must be changed every 10 days
Ref. JS20
Tf = -512ms
Maintenance Operating Mode:
In case of inopportune clamping, Release the clutch, then remove all the lots from the plate, then engage a new lot, and hit on the Restart button
MR23 TYPE Bottling machine
Previous screen
Web Utility©, Schneider Automation

Devices that Support FactoryCast Web Server Services

Device	
Quantum	140NOE77111
	140NWM10000
Premium	TSXETY110WS
	TSXETY5103
	TSXWMY100
Micro	TSXETZ510

3.10 FactoryCast HMI Web Server

At a Glance

Overview

The section describes the FactoryCast HMI Web service and how to use it for real-time plant diagnostics and control.

What's in this Section?

This section contains the following topics:

Topic	Page
FactoryCast HMI Web Services	237
Devices that Support The FactoryCast HMI Web Service	241

FactoryCast HMI Web Services

Summary

The FactoryCast HMI Web server extends the FactoryCast functions (see *p. 231*) by executing the following HMI Web features:

- real-time HMI database management (specific to the module and independent of the PLC processor)
- arithmetic and logical calculations for preprocessing data on the HMI
- transmission of electronic messages triggered by a specific process event (by email)
- connection to the SQL server and the MySQL and Oracle relational databases to archive tracking or logging data

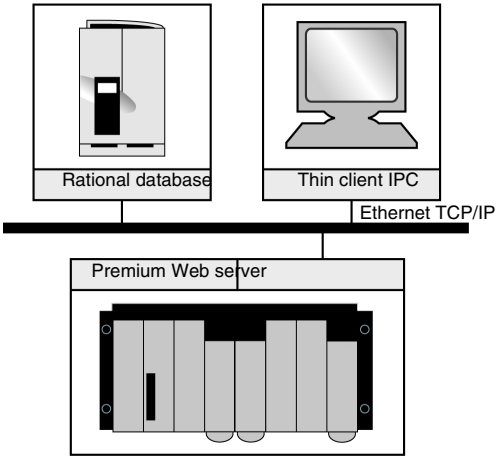
FactoryCast HMI is an active Web server that executes HMI functions integrated in a PLC module. The active Web server eliminates the need for communication via polling to update the HMI/SCADA database.

The FactoryCast HMI software configures the services on the module. You need only to configure the parameters for each service; no actual programming is required. The software provides a simulation mode to test the application without a FactoryCast HMI module or a physical connection to a PLC, thereby simplifying debugging.

FactoryCast HMI Web Service Operation

Although other Ethernet devices with an embedded Web server can provide real-time data, they are unable to provide historical information or initiate Web services unless a client is connected. The FactoryCast HMI devices have an integrated JVM. A FactoryCast HMI device can provide historical trending information and initiate other Web services such as database logging and email.

The following illustration shows the FactoryCast HMI Web service data flow:



Architecture

FactoryCast HMI Web servers can be integrated into:

- installations that require flexible and cost-effective HMI solutions
- hybrid architectures that supplement conventional SCADA systems
- architectures where direct links are required between automation systems and information management levels (IT links)

Flexible Web HMI Solution

FactoryCast HMI devices replace conventional HMI or SCADA solutions for architectures that require a flexible multi-station HMI. A FactoryCast HMI device provides a temporary remote control function over Internet or company networks. Typical architectures may consist of:

- several PLCs networked on an Ethernet network with FactoryCast HMI Web server modules
- one or more clients with a thin client interface equipped with a simple Web browser
- a relational database in which FactoryCast HMI can archive data directly from the automation system

FactoryCast HMI modules read PLC data and execute HMI services (email, interpreted calculations, connections to relational databases, updating Web pages) at source in the PLC, without affecting the PLC program or the CPU scan time.

This solution provides:

- a reliable HMI application executed at source in a PLC
- an integrated multi-station interface and remote access that is easy and cost-effective to set up (thin-client terminal)
- an HMI application that is easy to maintain because it resides in a single location on the server
- preventive maintenance notification via email
- data archiving directly from the data source

Hybrid Architectures

FactoryCast HMI supplements conventional SCADA systems. SCADA Vijeo Look or Monitor Pro software provides a means of centralizing information in order to perform global supervision from a central site.

Combining a FactoryCast HMI solution and a conventional SCADA solution enables:

- simplification of the SCADA application by locating some of the SCADA processing at the source level
- increased availability to trace data due to the direct connection between FactoryCast HMI modules and relational databases
- powerful ready-to-use remote diagnostics

Direct Links and Information Management Levels

In hybrid architectures, FactoryCast HMI eliminates the need for intermediate devices (gateways), which are expensive to install and maintain. It establishes a direct link between the automation levels and the global information management levels (MES, ERP, etc.). The PLC archives information directly from the automation system in relational databases, allowing a collaborative automation system to share data in real time. This solution results in:

- simplified architectures
- lower installation, development, and maintenance costs
- increased data reliability (because the data is collected at source)
- greater availability of data archiving

The HMI Tag Database

With an internal architecture similar to that of an HMI/SCADA system, FactoryCast HMI modules manage their own variable database in real time, independent of the PLC program. This variable database executes various functions, including internal processing, archiving, alarm, and email. Variables in this real-time database are updated by the automation system's data acquisition service. This service becomes operational once the following parameters have been set in the FactoryCast HMI software:

- direct import of PLC variable/symbol databases (without duplicate entries)
- definition of the acquisition frequency (the period at which this variable is updated)

Note: A FactoryCast HMI application running in a configured Premium FactoryCast HMI module can also access the remote PLC variables in the architecture via a transparent network (X-Way/Uni-TE transparent protocols).

Web Service Characteristics

FactoryCast HMI Web services have:

- a maximum of 1000 I/O variables from PLCs per application
- a maximum of 100 internal variables per application
- a minimum acquisition frequency of 500 ms

Connections to Relational Databases

The FactoryCast HMI module can be connected directly to the following remote relational databases:

- SQL server
- MySQL
- Oracle

This connection enables all internal or process data to be archived so that it can be logged and traced. The data can be archived (written) periodically and/or for a specific event. These variables can be from PLCs (I/O bits, internal bits, internal words, and registers) or local to the module.

The FactoryCast HMI roll-over function checks the size of tables by managing the maximum number of records. It is a circular data-archiving function that automatically deletes the oldest data. The roll-over function can be accessed by setting parameters in the FactoryCast HMI software.

Database Characteristics

Database characteristics are as follows:

- number of databases that can be connected: 3
- number of tables that can be written per database: 10 (maximum)
- number of columns per table: 50 (maximum)
- type of database supported: Oracle, SQL Server and MySQL
- automatic table creation: The FactoryCast HMI server automatically creates a table in the database

Calculation Functions

The FactoryCast HMI server can perform various arithmetic and logical operations on a combination of variables from the HMI database independent of the PLC processor. Some of these calculations include scaling, formatting, and logic processing for event triggering.

The calculation function comprises a set of spreadsheets with the formulae defined in cells. The spreadsheets are interpreted and processed by the server. The result of each formula is associated with a new internal variable. A user-defined trigger initiates the processing of each spreadsheet.

Devices that Support The FactoryCast HMI Web Service

Device	
Quantum	140NWM10000
Premium	TSXWMY100

3.11 Other Services

At a Glance

Overview

This section describes other support services available with some Transparent Ready devices. These services are implementations of standard IT infrastructure services that may be used for system maintenance and monitoring.

What's in this Section?

This section contains the following topics:

Topic	Page
FTP Service	243
SNMP Service	244
TFTP Service	246
Telnet Service	247
Quantum Device Support for Other Services	249
Other Services Supported by Premium Devices	251
Other Services Supported by TSX Micro Devices	253
Other Services Supported by Momentum Devices	253
Other Services Supported by Advantys STB Devices	254
Other Services Supported by Power Logic Gateways/Bridges	254
Other Services Supported by ConneXium Cabling Systems	255

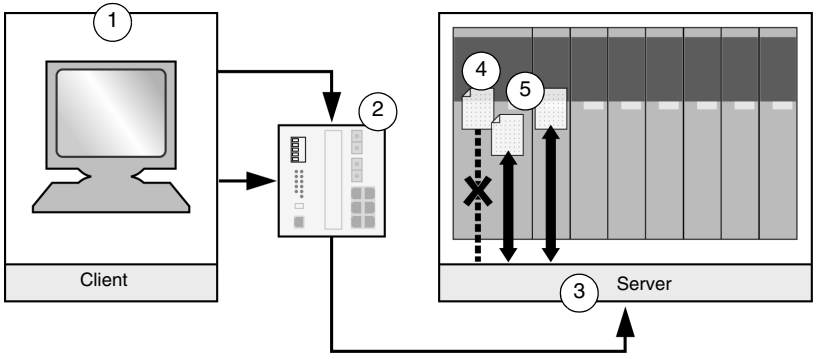
FTP Service

FTP Service Summary

FTP is a client-server protocol used by many systems to transfer files between devices. Many devices, including Transparent Ready devices, implement FTP to transfer information to load new firmware, custom Web pages, etc.

FTP transports and exchanges all information using TCP. By default, FTP uses TCP port number 20 for data transport and TCP port number 21 for control. The client initiates an FTP connection by connecting to the control port on the server. The server responds by connecting the data port back to the client. After the connections are made, file transfer can take place.

In Transparent Ready devices, FTP may be used for different purposes depending on the device. For example, only firmware and custom Web pages are accessible on Transparent Ready CPUs through the FTP server. CPU program files cannot be accessed.



1 an FTP client PC
2 an Ethernet switch
3 a PLC with FTP server connections
4 a PLC program with no path to the FTP server
5 HTML Web page files

FTP Security

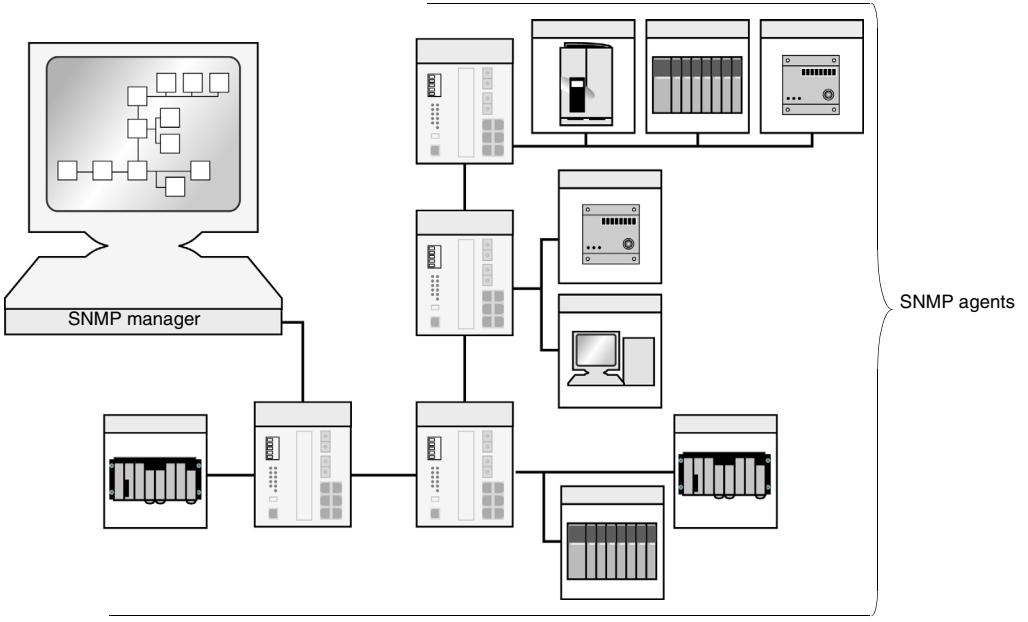
The client must provide a username and password in order to read or write files on the server. However, the transmission of this authentication information is done in simple text; therefore it can be obtained by inspecting the content of the messages between the client and the server.

The transmission of files over or outside of a network is a major concern when firewalls are implemented to control access and information flow. Therefore unless the FTP port is open in the firewall, this type of communication is blocked. For information on how to open ports on firewalls, refer to the firewall documentation (see *p. 150*) or contact your company's IT department.

SNMP Service

Summary

With the SNMP service, you can monitor the status of the network and the devices connected to it. This service supports the management of many diverse network devices using a single system. It consists of the network management system, the SNMP protocol, and the SNMP agent in each network device.



The SNMP protocol is used to exchange network management information between the network manager or management system (such as HP Openview, IBM Netview, etc.) and the SNMP agents.

SNMP Service Operation

The information available in a device is listed in a data structure called a *management information base* (MIB). A MIB contains data definitions of the attributes for each of the network-managed objects so that the management system can gather and combine information from multiple devices. The SNMP service monitors the state of the network, modifies device configurations, and generates alarms based on device failures.

Many standard MIBs have been developed (MIB-II, Switch MIB, etc.). Devices implement these MIBs to provide standard information to any network management system. Depending on the device complexity, manufacturers may choose to implement private MIBs that provide additional information specific to their device.

The SNMP protocol transports and exchanges all information using UDP. UDP's small and simple packet size reduces the network load. However, extensive monitoring can cause increased network load.

SNMP Security

Since the introduction of SNMP, protecting network management information has become an increasingly important issue. In SNMPv1, requests and replies are sent in clear text, exposing variables to hackers. MIB writers discovered that some data type definitions required more precision. SNMPv2 addressed these issues by improving the authentication of the message source, protecting these messages from disclosure, and placing access controls on the MIB database. However, some security aspects still remained vulnerable. SNMPv3 framework augments the original SNMPv1 and v2 specifications with additional security and administration capabilities.

TFTP Service

TFTP Service Summary

TFTP is a simple client/server protocol that may be used instead of FTP to transfer files. It uses UDP port number 69 and is implemented on top of the UDP transport layer. With TFTP most of the features of a regular FTP are removed. It can perform only read and write operations from/to a remote server; it cannot list directories, and it has no provisions for user authentication or security. TFTP can be implemented in simple devices.

During a TFTP connection, files are transferred between the client and the server. The recipient of the file issues a confirmation that the file was received without errors.The protocol does not permit retransmission of only part of a file that contains an error; the entire file must be retransmitted. This can represent a delay in the transmission time. However, the probability of errors in the file due to transmission or transmission loss is not very high.

As with the FTP service in Transparent Ready devices (see *p. 243*), TFTP uses are device-dependent. For example, on a Modbus serial-to-Modbus Ethernet bridge, the firmware is transferred using TFTP, but the device configuration file cannot be. To establish a connection with the server, a client (such as WSFTP or Windows TFTP client) is required.

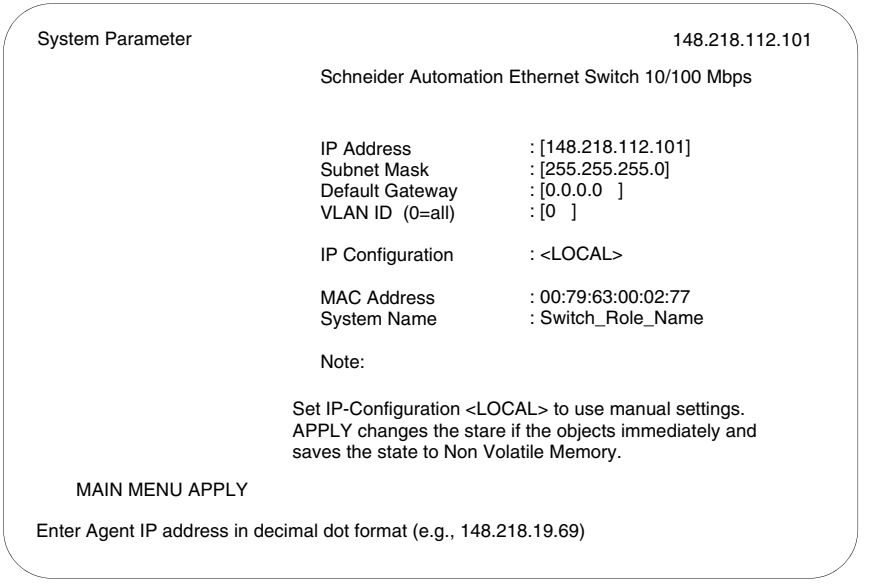
Telnet Service

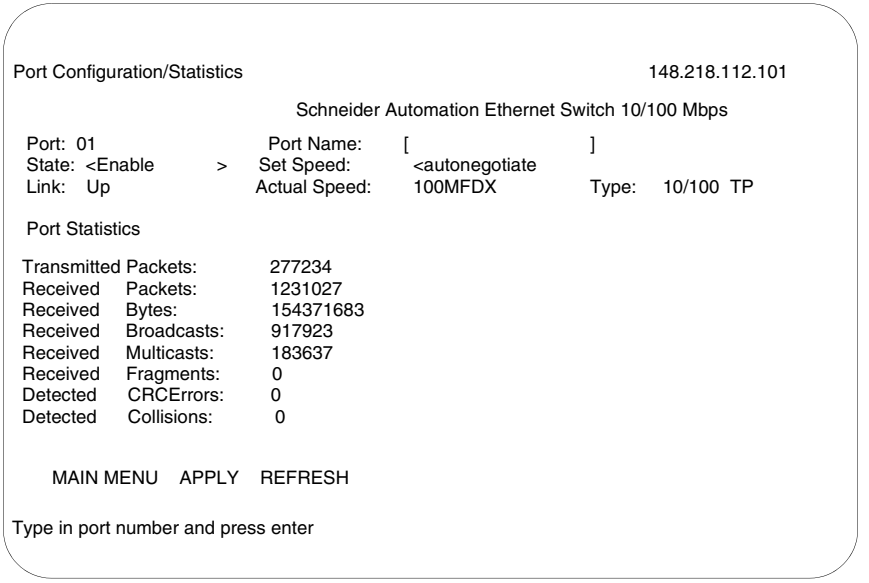
Telnet Service Summary

The Telnet protocol provides an interactive, text-based communications session or user interface between a client and a host. Telnet interfaces can be used for tasks such as device configuration, diagnostics, and file interchange.

The Telnet protocol runs over the TCP transport layer using port 23. A Telnet session can generate unexpected amounts of network overhead, because each keystroke may be sent as a separate TCP packet.

Here are examples of a configuration screen and a diagnostics screen for the ConneXium Ethernet Switch (499NES27100):


System Parameter
148.218.112.101
Schneider Automation Ethernet Switch 10/100 Mbps
IP Address : [148.218.112.101]
Subnet Mask : [255.255.255.0]
Default Gateway : [0.0.0.0]
VLAN ID (0=all) : [0]
IP Configuration : <LOCAL>
MAC Address : 00:79:63:00:02:77
System Name : Switch_Role_Name
Note:
Set IP-Configuration <LOCAL> to use manual settings.
APPLY changes the stare if the objects immediately and
saves the state to Non Volatile Memory.
MAIN MENU APPLY
Enter Agent IP address in decimal dot format (e.g., 148.218.19.69)



Telnet Security

The Telnet protocol implements a username and password that the client must use to gain access to the Telnet session. In some cases the Telnet servers implement different usernames/passwords for access to different device configuration options. However, the transmission of this authentication information is done in simple text, and therefore it can be obtained by inspecting the content of the message.

Quantum Device Support for Other Services

SNMP

Device	SNMP(v1)	SNMP(v2)	SNMP(v3)	MIB-II	TFprivate-MIB
140CPU65150	X	-	-	X	X
140CPU65160	X	-	-	X	X
140NOE77101	X	-	-	X	X
140NOE77111	X	-	-	X	X
140NWM10000	X	-	-	X	X

FTP

Device	Firmware	Web Files	Security	FDR Support
140CPU65150	X	X	X	X
140CPU65160	X	X	X	X
140NOE77101	X	X	X	X
140NOE77111	X	X	X	X
140NWM10000	X	X	X	-

TFTP

Device	FDR Support
140CPU65150	X
140CPU65160	X
140NOE77101	X
140NOE77111	X
140NWM10000	X

Telnet

Device	Configuration	Diagnostics[1]	Security	Levels of Security
140CPU65150	-	X	X	X[2]
140CPU65160	-	X	X	X[2]
140NOE77101	-	X	X	X[2]
140NOE77111	-	X	X	X[2]
140NWM10000	-	X	X	X[2]
[1] For factory use only				
[2] multiple passwords				

Other Services Supported by Premium Devices

SNMP

Device	SNMP(v1)	SNMP(v2)	SNMP(v3)	MIB-II	TFprivate-MIB
TSXP571634M	X	-	-	X	X
TSXP572634M	X	-	-	X	X
TSXP573634M	X	-	-	X	X
TSXP574634M	X	-	-	X	X
TSXP575634M	X	-	-	X	X
TSXETY4103	X	-	-	X	X
TSXETY110WS	X	-	-	X	X
TSXETY5103	X	-	-	X	X
TSXWMY100	X	-	-	X	X

FTP

Device	Firmware	Web Files	Security	FDR Support
TSXP571634M	X	X	X	X
TSXP572634M	X	X	X	X
TSXP573634M	X	X	X	X
TSXP574634M	X	X	X	X
TSXP575634M	X	X	X	X
TSXETY4103	X	X	X	X
TSXETY110WS	X	X	X	-
TSXETY5103	X	X	X	X
TSXWMY100	X	X	X	-

TFTP

Device	FDR Support
TSXP571634M	X
TSXP572634M	X
TSXP573634M	X
TSXP574634M	X
TSXP575634M	X
TSXETY4103	X
TSXETY110WS	X
TSXETY5103	X
TSXWMY100	X

Telnet

Device	Configuration	Diagnostics[1]	Security	Levels of Security
TSXP571634M	-	X	X	X[2]
TSXP572634M	-	X	X	X[2]
TSXP573634M	-	X	X	X[2]
TSXP574634M	-	X	X	X[2]
TSXP575634M	-	X	X	X[2]
TSXETY4103	-	X	X	X[2]
TSXETY110WS	-	X	X	X[2]
TSXETY5103	-	X	X	X[2]
TSXWMY100	-	X	X	X[2]
[1] For factory use only				
[2] multiple passwords				

Other Services Supported by TSX Micro Devices

FTP

Device	Firmware	Web Files	Security	FDR Support
TSXETZ410	X	X	X	X
TSXETZ510	X	X	X	X

Other Services Supported by Momentum Devices

SNMP

Device	MIB-II	TFprivate-MIB
170ENT11001	X	X

FTP

Device	Configuration	Web Files	Security
170ENT11001	X	X	X

Telnet

Device	Configuration	Diagnostics	Security
171CCC96020	-	X	X
171CCC96030	-	X	X
171CCC98020	-	X	X
171CCC98030	-	X	X
170ENT11001	X	X	X

Other Services Supported by Advantys STB Devices

SNMP

Device	SNMP(v1)	SNMP(v2)	SNMP(v3)	MIB-II	TFprivate-MIB
STBNIP2212	X	-	-	X	X

FTP

Device	Configuration	Web Files	Security
STBNIP2212	X	X	X

Other Services Supported by Power Logic Gateways/Bridges

SNMP

Device	SNMP(v1)	SNMP(v2)	SNMP(v3)	MIB-II	TFprivate-MIB
EGX 200	X	-	-	X	-
EGX 400	X	-	-	X	-

FTP

Device	Configuration	Web Files	Security
EGX 200	-	X	X
EGX 400	X	X	X

Other Services Supported by ConneXium Cabling Systems

SNMP

Device	SNMP(v1)	SNMP(v2)	SNMP(v3)	MIB-II	TFprivate-MIB
499NES17100	X	-	-	X	X
499NOS17100	X	-	-	X	X
174CEV30020	X	-	-	X	-
174CEV20030	X	-	-	X	-
174CEV20040	X	-	-	X	-

FTP

Device	Configuration	Web Files	Security
174CEV20040	X	X	X

TFTP

Device	Configuration	FDR Support
499NES17100	-	-
174CEV30020	X	X
174CEV20030	X	X

Telnet

Device	Configuration	Diagnostics	Security
174CEV30020	X	X	X
174CEV20030	X	X	X

3.12 OPC Factory Server

At a Glance

Overview

This section describes OFS (OPC Factory Server) and provides examples of how to implement these servers in Transparent Ready systems.

What's in this Section?

This section contains the following topics:

Topic	Page
OPC Factory Server	257
OFS Services	261
OFS Performance	264
Runtime Architecture for Unity/OFS/SCADA: a Simple Example	267
Build-time/Runtime Architecture for Unity/OFS/SCADA Systems that Are Not Frequently Modified	268
Build-time/Runtime Architecture for Unity/OFS/SCADA Systems that Require Frequent Modification	270
Build-time/Runtime Architecture for a System with Multiple SCADA Connections	272

OPC Factory Server

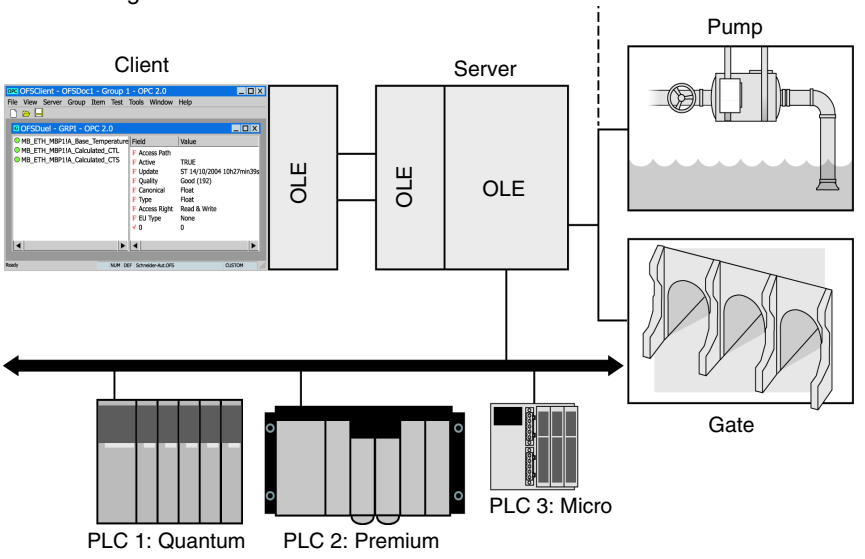
Summary

OPC data access is used to move real-time data from PLCs, DCSs, and other control devices to display clients such as HMI panels. The OPC specification defines a standard set of objects, interfaces, and methods for interoperability in process control and manufacturing automation applications. The specification was originally based on Microsoft's OLE component object model and distributed component object model technologies.

OPC factory server (OFS) is a multi-controller data server that can deliver data to OPC clients and can communicate with Compact, Micro, Momentum, Premium, Quantum, TSX Series 7, and TSX S1000 PLCs. OFS provides the client applications with a group of services (called *methods*) for accessing control system variables. OFS is a PLC data access OPC server that is compliant with OPC 1.0A and OPC 2.0; it functions with any OPC-compliant client and with two types of OPC-compliant software:

- supervisory software: the OFS assumes the role of a driver by ensuring communication with all Transparent Ready devices
- custom supervisory software: using either the OLE automation interface or the OLE custom interface

The following illustration shows an OFS interface:



OFS provides the interface between Schneider Electric PLCs and one or more client applications in which some of the device data values are viewed and/or modified.

OFS Capabilities

OFS supports:

- multiple devices
- multiple communication protocols
- multiple clients
- access to devices and variables by address or by symbol
- access to the server in local or remote mode
- a notification mechanism that enables values to be sent to the client only when these values change state
- automatic determination of the size of network requests depending on the device type
- service availability via both the OLE automation and OLE custom interfaces
- compatibility with OPC Data Access standards, both version 1.0A and 2.0

Data Exchange Modes

OFS supports two modes for exchanging data with the PLC:

- default classic (polling) mode
- *push data* mode, where data is sent at the initiative of the PLC

Push data is recommended when changes of state are infrequent.

OFS Services

OFS offers the following services:

- reading and writing of variables in one or more PLCs present on one or more different networks
- a user-friendly configuration tool that explains the parameters needed for the server to function efficiently
- a tool enabling parameters to be modified online to maximize utilization flexibility
- the ability to use a list of symbols for the PLC application
- a browser interface that provides a graphical understanding of the accessible devices and their associated symbols
- a list of specific device-dependent items that enables functions such as status, start/stop of the PLC, and alarm supervision to be executed

Communication with the PLC

OFS operates with the Quantum, Premium, Micro, Momentum, Compact, Series 7, and S1000 PLC ranges on the following networks:

- Modbus Serial (RTU)
- TCP IP (IP or X-Way addressing)
- Modbus Plus
- Uni-Telway
- Fipway
- Ethway
- ISAway
- PCIway
- USB

OFS is compatible with the Nano on a Uni-Telway network, with these restrictions:

- read operations only
- access to a single word or x bits within 16 consecutive bits

The following table outlines OFS 3.1 compatibility with devices in the Schneider Electric SA range and the different networks:

Network	Premium	Micro	Series 7	Series 1000
Ethway	TSXETY110 (Ethway)		TSXETH107 TSXETH200	ETH030
TCP/IP	TSXETY110 (TCP/IP) TSXETY410 (TCP/IP) Built-in channel TSXETY510 (TCP/IP)	TSXETZ410 TSXETZ510		
Uni-Telway	Built-in channel TSXFPP20	Built-in channel TSX FPP20	TSX SCM22	
Fipway	TSXFPP20	PCMCIA TSXFPP20	TSXP7455 TSXFPP20	
ISAway	ISA Bus			
PCIway	PCI Bus			
Modbus	TSXSCP11		TSXSCM22	JB cards
Modbus Plus	TSXMBP100	TSXMBP100		
USB	Built-in channel			

	Quantum	Momentum	Compact
TCP/IP	140NOE771 Built-in channel	171CCC96030 171CCC98030	
Modbus	Built-in channel	171CCC760 171CCC780	Built-in channel
Modbus PLus	Built-in channel		Built-in channel
USB	Built-in channel		

Definition of Group of Items

OFS services are all based on the concept of a group of items. An item is a variable of any PLC that can be accessed either by their address or by their symbol. OFS groups are characterized as follows:

- Several groups may be defined.
- A group may involve several devices. Each item in a group may have a different device address.
- A group involves various communication devices and media. Each item may refer to a different communication driver. If a device can be accessed via several communication media, it is possible to mix variables addressed via different media within one group.
- The items comprising a group may be different. It is possible to mix all types of objects managed by the OFS, for example, mixing words, double words, and floating points in one group.
- All the items in the same group have the same update rate and deadbanding percentage.

OFS Services

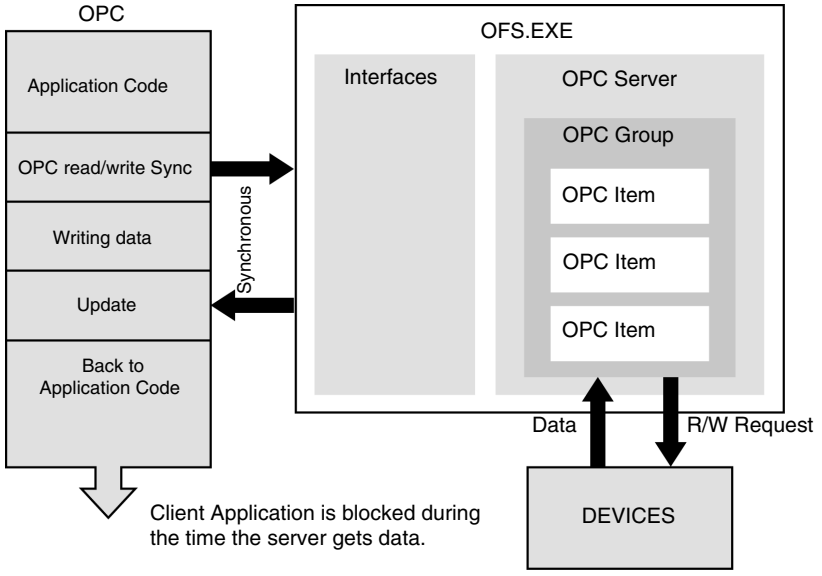
Synchronous Services

Synchronous services are used to:

- partially or completely read and write a group of items
- periodically scan variables (read polling) that must be handled by the client application

The term *synchronous* means that the client application that calls a read or write service is blocked for the time it takes to obtain a result. The instruction that follows a synchronous read or write call in the code of the client application is executed only after all the communication requests corresponding to that call have been processed. During a synchronous read operation, OFS does not guarantee that all the variables in a group will be accessed in the same CPU scan if the group is transcribed on several communication requests. An OFS mechanism ascertains the number of requests necessary to access the whole of a group of items (for synchronous groups only).

The conditions that permit the items in a group to be consistent with one another (read or written in the same CPU scan) are described in the OPC Factory Server manual.



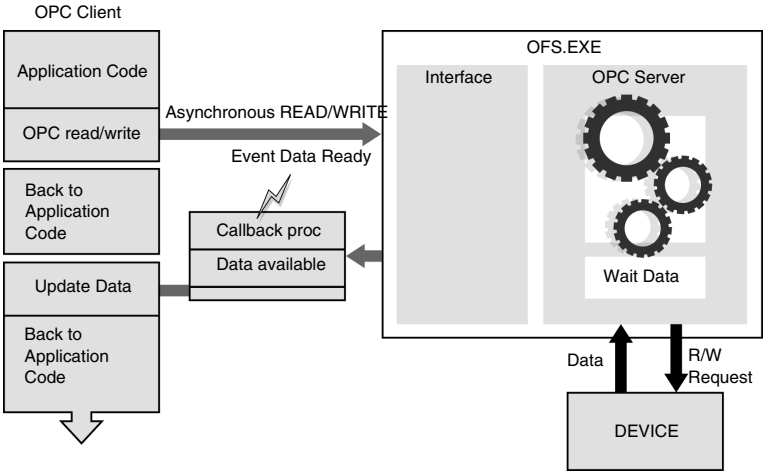
Asynchronous Services

In asynchronous mode, a request for any asynchronous operation receives an immediate response. The operation requested has either been refused (incorrect code response) or is underway (correct code response); it has not been completed.

The completion and the outcome of the operation is announced via the notification mechanism. This mechanism must be activated before starting an asynchronous operation.

Read, Write, Refresh, and Cancel operations are used to partially or completely read and write a group of items. The client application must periodically scan the evolution of variables (read polling). The client application is not blocked during the time it takes to obtain the data. The activated notification mechanism then announces the results to the client.

Synchronization with the PLC is the same as the process outlined for synchronous services.



Notification Service

OFS performs read polling and notification of changes in variable values. The client application needs a wake-up function programmed into it. The OFS should call the wake-up when the values of items in periodically examined groups change.

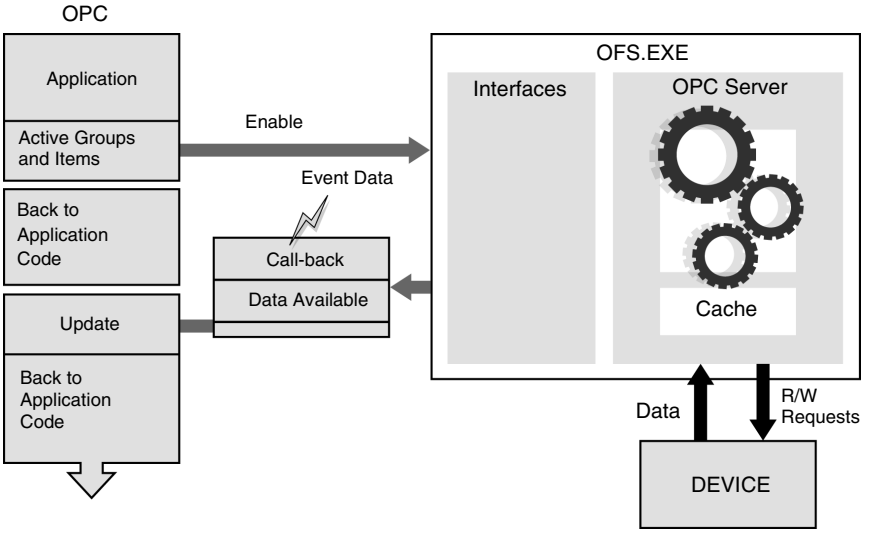
The wake-up function must be unique in the client application. It receives all the notifications from the OFS, then it redistributes them to the processing functions specific to each periodically scanned group.

Note: For ready-to-run supervisory software, the wake-up function should be pre-programmed. If this is not the case, do not use the notification mechanism.
The OPC standard OnDataChange sets the name of this wake-up function. The OFS notifies by group, not by individual items. For a given group, the OFS sends the client application wake-up function a list of items whose value has changed. In the case of a table type item, the OFS transmits the whole table even if only a subset of the elements has changed values.

Note: In the wake-up function, processes that take up a significant amount of CPU time (e.g., an overly complex display) should not be performed. These kinds of processes can adversely affect the Operating System's performance.

The following issues relate to the notification service:

- Assigning a scanning period (rate) to a group enables you to scan the PLC variables at different periods. For example, you can display the PLC time every second and the temperature every minute.
- Allocate deadband to a group so that notifications are filtered when group variable values change. Notification occurs if variables change by more than a certain percentage of their previous value after the group scanning period. For example, the client application is informed only if temperature changes by more than 10%.



Note: Deadbanding is applied only to floating-point or integer variables so that you can control (or limit) the flow of notifications sent to the client application and thereby avoid overloading the system.

OFS Performance

Summary

The following discussion describes the static characteristics of OFS and defines some rules for generating and optimizing network requests. The purpose for these rules is to minimize the number of requests as much as possible.

Maximum Size of a Request

The table that follows specifies the maximum number of data bytes that can be compacted into a single request. Any data items accessed in the same request are from the same PLC cycle and so are consistent in size. The byte sizes given in the table can be used to calculate the number of items of the same type that can be read or written in a PLC communication request. A word takes up 2 bytes, a double word 4 bytes, and a floating-point word 4 bytes.

Count 8 bits per byte except when you are reading with a PL7 PLC on an XWAY network, in which case each byte contains only 4 bits.

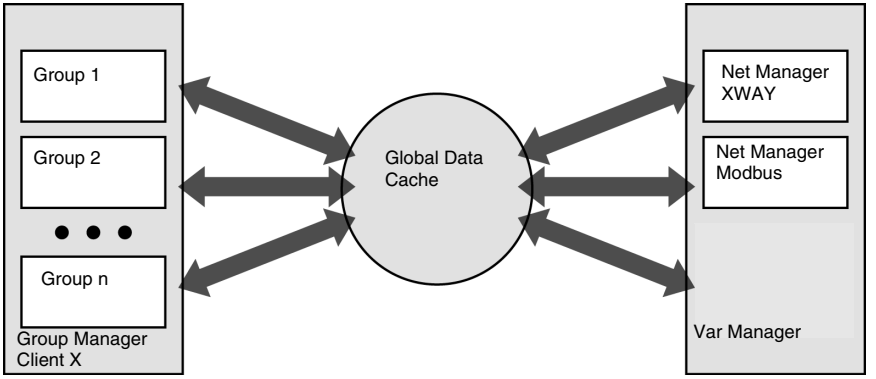
For example, on a PL7 PLC running on XIP, 248%MB, 62%MD,124%MW, or 992%M can be read in one request, and 244%MB, 61%MD, 122%MW or 1960%M can be written in 1 request.

The following table lists the number of data bytes that can be compacted in one Unity Pro device request:

Communication Medium	Read	Write
XIP	249	235
XIP Built-in channel	256	242
TCP/IP	1022	1008
PCIway	224	210
USB	1022	1008
USB X-Way (USBX)	1020	1006
Fipway	123	109
Uni-Telway	241	227
Ethway	249	235
Modbus Plus	250	236
Modbus RTU	249	235

Use of Groups

Dividing items into different groups can have an effect on the construction of network requests. For each device, the items are separated into independent sets if necessary. However, the sets are not determined by the groups themselves, but by the Group Min update rate.



The groups do not influence the generation of network requests. Declaring items in two different groups with the same update rate generates the same number of requests as declaring items in a single group.

Requests are generated in batches made up of items belonging to groups with the same period. They are not generated within a group.

Optimizing Requests

Each set of items is optimized individually corresponding to a device and a frequency. Optimization algorithms act in two stages:

- *compacting*: grouping items of the same type (with similar or consecutive addresses) in tables. For writing, grouping is performed only if the items are strictly consecutive. Obtain a list of elements from the original items to send to the PLC to read or write. On Series 7 PLCs, compacting is not performed on unitary bits; for bit tables, it is performed only if the number of bits is a multiple of 8.
- *concatenating*: constructing requests by optimizing the possibilities of the protocol. Certain protocols let you define access to different types of objects in the same request. OFS automatically adjusts the size of requests to the maximum that is admissible.

Unity devices use both compacting and concatenating for optimization.

The located and unlocated variables in the Modbus read request generator provide a mixing technique (*read block offset length*). The read request generator can mix any variable type in the same request; one variable equals one 6-byte identifier. The NOE module can send only 1 request per CPU scan for unlocated variables and 4 requests per CPU scan for registers.

For example, sending 1 Boolean, 2 floating-point integers, and a structure with 5 integers would equal or exceed 1 request:

%MW2, %MW3, %MW40, %mX5, %MX8 => 1 request with 3 elements (MW2 ... 3, MW40, MWX5 ... 8)

Dynamic Performance

The dynamic performance of OFS can be measured against several characteristics:

- configuration response time
- read/write response time
- volume of data exchanged
- sensitivity to errors

It can also be measured along 2 lines:

- OFS communication with devices
- OFS communication with OPC clients

In certain cases, you must configure different OFS parameters to obtain better performance; for example, if devices are accessed via different types of networks and a lower-performance network is used somewhere on the network path. One of the server adjustment parameters that influences performance for OFS communication with devices is the multichannel feature.

Refer to the OPC Factory Server manual for more information about the diagnostic window, which holds the server and communication status.

Multichannel Feature

Most of the communication protocols used by OFS are half-duplex; after sending 1 request, the server waits for the answer before sending the next request. (The exception is XWAY for Unity or PL7 PLCs.) With half-duplex networks, the only way to speed up the communication is to open more than 1 channel between the sender and the receiver. You can open between 1 and 16 channels for each device, and you can configure that number either statically with the OFS configuration tool or dynamically with the specific #MaxChannel.

The value that gives optimal performance depends on the PLC being accessed (i.e., the number of requests it can process per cycle) and the communication card being used (most notably on Concept PLCs). To obtain this data, refer to the PLC and communication card documentation.

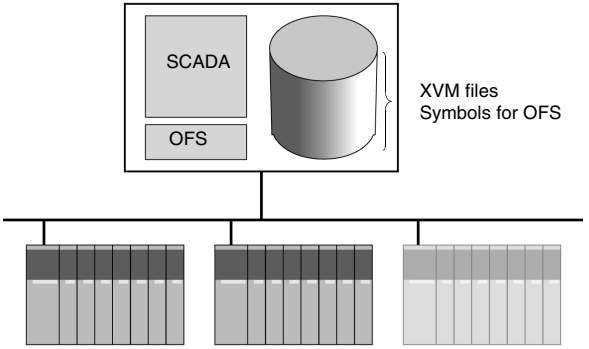
Note: The multi-channel function is not significant for Unity Pro or PL7 PLCs that use an XWAY (full-duplex) network and with serial Modbus drivers (single-channel only) on any PLC types.

On half-duplex networks a parameter can be used to send several requests to a device simultaneously; the higher the value, the better the performance for communication with the device.

Runtime Architecture for Unity/OFS/SCADA: a Simple Example

Sample Architecture

The following runtime example is for simple architectures where the PLC application does not need on-line modifications.



VijeoLook is the best choice for this type of architecture. Only one PC is used to run both the SCADA and OFS software. The maximum number of PLCs on a system like this is five.

Runtime System Options

On Ethernet TCP/IP only, you can locate the XVM symbols file on another PC instead of the one that runs the SCADA and OFS. This option lets you centralize the resources on one PC that can be easily backed up. This implementation may be necessary when the system is integrated in larger architecture.

Key System Characteristics

- The runtime system needs the Unity Pro XVM symbols file to be compatible with OFS. The symbols file is exported in Build mode by Unity Pro and must be copied on the PC that is used to run the system. A symbols file is needed for each PLC application.
- The SCADA + OFS + XVM files system runs on one PC.
- OFS accesses the data in the PLC in real time. Any discrepancies between the running application and the local symbols file on the PC initiates signature checking. In accordance with QoS for OFS, the communication stops or switches to a bad quality service. You need to manually update the PC with the correct symbols file in order to have consistency between the symbols file and the application running in the PLC.

Product Versions

Product	Version	Comments
Unity Pro M, L, XL	2.0	
VijeoLook	2.6	includes the correct version of OFS

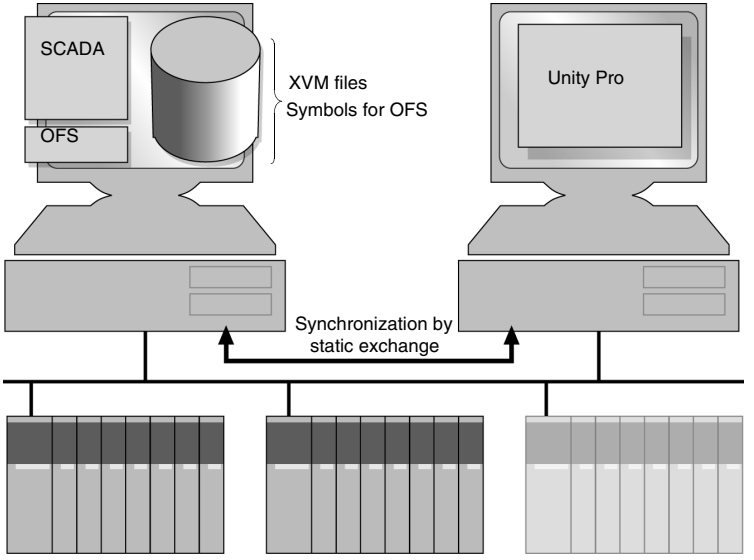
Build-time/Runtime Architecture for Unity/OFS/SCADA Systems that Are Not Frequently Modified

Sample Architecture

The following example of a build-time/runtime system supports architectures that:

- do not require frequent modifications of the application
- have a low constraint on synchronization between the SCADA and the running application during modifications

The synchronization between the Unity Pro database and OFS is managed manually; there is static exchange of the symbols file.



With VijeoLook as the SCADA, a maximum of 5 PLCs can be supported. For larger configurations, use Monitor Pro. One PC is used to run both the SCADA and OFS software. Another PC is used to run Unity Pro on the PLC applications.

Build-time/ Runtime Option

On Ethernet TCP/IP only, you may locate the XVM symbols file on a different PC than the one that runs the SCADA and OFS. This option lets you centralize the resources on one PC that can be easily backed up. This implementation may be necessary when the system is integrated in a larger architecture.

Key System Characteristics

- The runtime system needs the Unity Pro XVM symbols file to be compatible with OFS. The symbols file is exported in Build mode by Unity Pro and must be copied on the PC that is used to run the system. A symbols file is needed for each PLC application.
- The SCADA + OFS + XVM files system runs on one PC.
- Unity Pro runs on a separate PC for application modifications. This PC is not necessarily connected to the network permanently; it may be connected only for on-line modification or XVM file copying to the OFS system.
- OFS accesses the data in the PLC in real time. Any discrepancies between the running application and the local symbols file on the PC initiates signature checking. In accordance with QoS for OFS, the communication stops or switches to a bad quality service. You must manually update the PC with the correct symbols file in order to have consistency between the symbols file and the application running in the PLC.

The update can be triggered by the SCADA application through a specific command mode of OFS. The application does not stop. Only the OFS communication is interrupted during the symbols file update.

Product Versions

Product	Version	Comments
Unity Pro M, L, XL	v2.0	
VijeoLook	v2.6	includes the correct version of OFS
MonitorPro	v7.2	without access to the structured variables

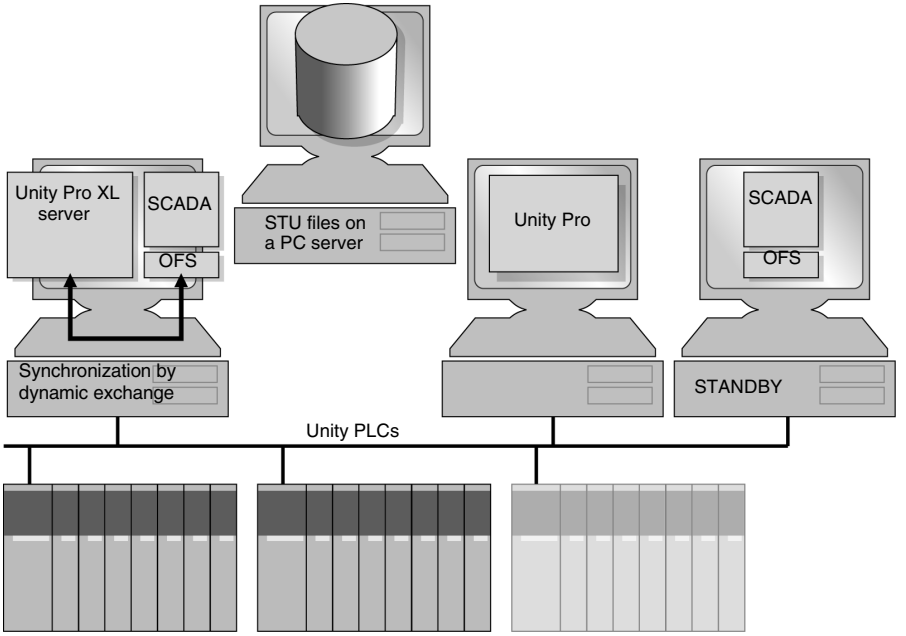
Build-time/Runtime Architecture for Unity/OFS/SCADA Systems that Require Frequent Modification

Sample Architecture

The following example of build-time/runtime system supports architectures that require:

- frequent application modifications
- a higher level of service for synchronization between the SCADA and a running application during modifications

Synchronization is managed through dynamic exchanges between OFS and Unity Pro XL. No manual operation is necessary to update the symbols file for OFS.



One PC is used for the SCADA, OFS and Unity Pro XL in server mode. Another PC is used to run Unity Pro for application modifications, and a third PC is required to achieve redundancy for Monitor Pro. The PC server for the STU application files enables consistency to access from either the OFS / Unity Pro XL system and the Unity Pro to the same application.

Build-time/ Runtime Options

The architecture described above is recommended for a (normal/standby) redundancy system for Monitor Pro.

In architectures that do not require redundancy, the STU application file can be located on the PC where the OFS/SCADA and the Unity Pro XL system are running.

Key System Characteristics

- Unity Pro XL is necessary for the operating modes of OFS; it is the only package able to run the server mode that is mandatory for the dynamic symbol update. Unity Pro XL must be installed. OFS launches Unity Pro XL and opens the application in background mode.
- The SCADA + OFS + Unity Pro XL system runs on one PC.
- Unity Pro runs on a separate PC for application modifications. This PC does not need to be connected to the network permanently, only for on-line modifications.
- When a PC server is used for the STU application files, OFS and Unity Pro use the same application for the modifications and synchronization.
- OFS accesses the data in the PLC in real time. It detects any discrepancies between the running application and the local symbols file on the PC (signature checking). In accordance with the OFS QoS, communication stops or switches to a bad quality service.
- OFS/Unity Pro XL updates the symbols by accessing the STU file. Depending on the OFS settings, this update can be automatic or triggered by the SCADA application by a specific command mode in OFS. The application does not stop. Only the OFS communication is interrupted during the symbol file update.
- When Unity Pro handles on-line modifications, the STU application file handles the synchronization of OFS/Unity Pro XL with the right version of the application.

Product Versions

Product	Version	Comments
Unity Pro M, L, XL	v2.0	for the application modifications
VijeoLook	v2.6	includes the correct version of OFS
MonitorPro	v7.2	without access to the structured variables

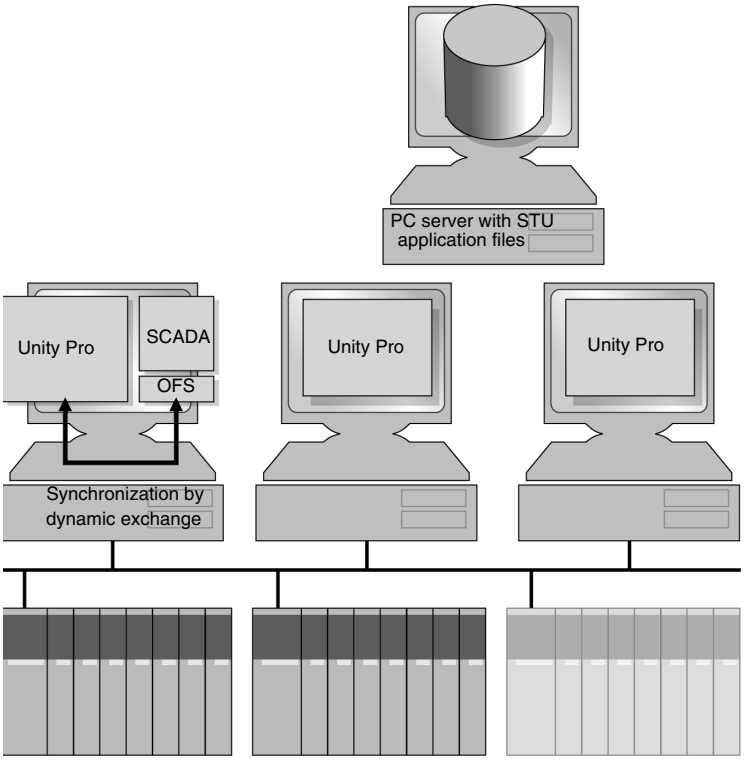
Build-time/Runtime Architecture for a System with Multiple SCADA Connections

Sample Architecture

The following example of a build-time/runtime system supports architectures that require:

- frequent application modifications
- a higher level of service for synchronization between the SCADA and the running application during modifications

This architecture also supports multiple SCADA connected on one centralized OFS. The synchronization is managed through dynamic exchanges between OFS and Unity Pro XL. Manual operation is not needed to update the symbols file for OFS.



One PC is used to run both OFS and Unity Pro XL in server mode. One or several PCs are dedicated for the SCADA. Another PC is used to run Unity Pro for application modifications

The PC server for the STU application files provides the consistency needed so that all the stations running Unity Pro can access the same, up-to-date application information.

System Option

The STU application file can be located on the same PC where the OFS/SCADA and Unity Pro XL system run.

Key Characteristics of the System

- Unity Pro XL is needed for the OFS operating modes. This is the only architecture that lets you run in server mode, which is mandatory for the dynamic update of the symbols. Unity Pro XL must be installed. OFS launches Unity Pro XL and opens the application in background mode.
- The OFS + Unity Pro XL system runs on one PC.
- The SCADA is executed on a dedicated PC and communicates with OFS (DCOM) for real-time access to the PLC.
- Unity Pro runs on a separate PC for application modifications. This PC does not need to be connected to the network permanently, but only for on-line modification.
- The PC server for the STU application files provides consistency so that all the OFS and Unity Pro stations use the same application data for the modifications and synchronization.
- OFS accesses the data from the PLC in real time. It detects any discrepancies between the running application and the local symbol file on the PC (signature checking). In accordance with the OFS QoS, the communication stops or switches to a bad quality service.
- OFS/Unity Pro XL updates the symbols by accessing the STU file. Depending on the OFS settings, this update can be automatic or triggered by the SCADA application through a specific command mode in OFS. The application does not stop. Only the OFS communication is interrupted during the symbol file update.
- Any on-line modifications from Unity Pro imply saving the STU application file so that OFS / Unity Pro XL is synchronized with the right version of the application.

Product Versions

Product	Version	Comments
Unity Pro M, L, XL	2.0	for the application modifications
Unity Pro XL	v2.0	for the PC server mode
VijeoLook	v2.6	includes the correct version of OFS
Monitor Pro	v7.2	without access to the structured variables

3.13 SCADA/HMI

At A Glance

Overview

This section describes the operation and design of a SCADA or HMI system. It focuses on the use of the Modbus TCP/IP communications protocol between the SCADA system and the end devices. The information is not specific to a particular SCADA system or HMI package; the concepts described apply to most packages on the market, but terms and techniques may vary between packages.

What's in this Section?

This section contains the following topics:

Topic	Page
SCADA/HMI	275
I/O Server to Field Device Communications	277
SCADA Communications to Field Devices: Socket and Request Usage	281
I/O Server and Display Client Communications	285
Schneider Product Implementation Details	286

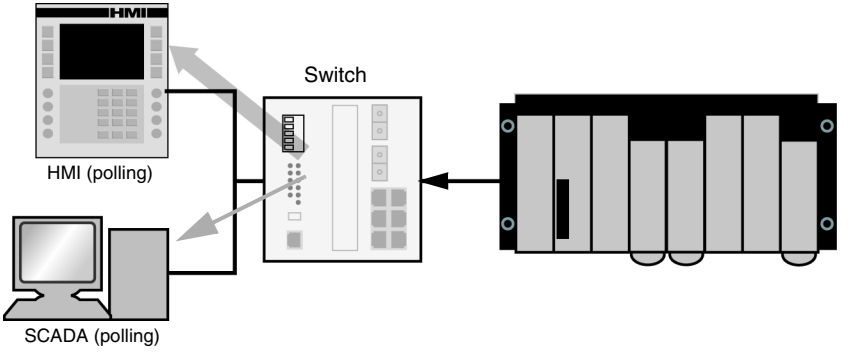
SCADA/HMI

SCADA/HMI Models

SCADA and HMI systems are represented by two models: standalone and client/server.

Standalone Model

The standalone SCADA/HMI model uses the same computer or terminal to poll and display data from devices in the field. Each additional display terminal polls its own data from the field devices. This illustration shows an HMI and a PC with SCADA polling a PLC for data.

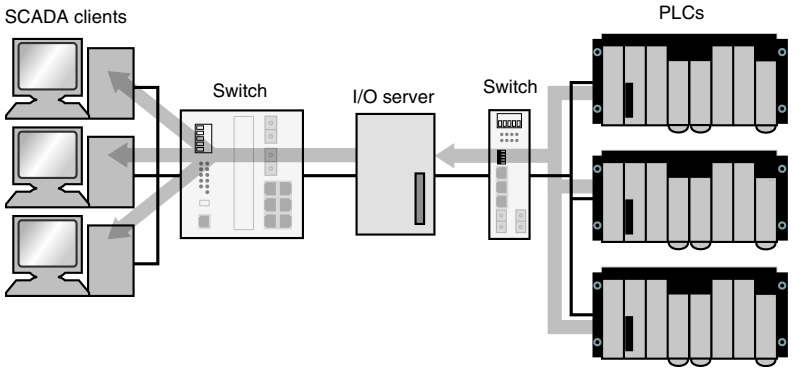


Client/Server Model

The client/server model uses a separate I/O server and display clients. The I/O server polls data from the field devices and the clients display the data. Each client obtains the data from the I/O server, not the field devices. The I/O server combines all the requests from the display devices and gathers the required data from the field devices to the SCADA system. As a result, the load on the network and the field devices is lower, and the system response time improves. In some systems, the I/O server can be the same physical device as the display device.

Note: Multiple I/O servers can be used to enable redundancy.

This illustration shows that the requests from the SCADA client are being obtained from the PLCs by the I/O server.



A SCADA system may include other servers such as trending, alarms, etc. These servers are not included in the description here because they use the I/O server to communicate with the field devices.

The data used by the SCADA system are called *tags*. Tags can be used for display, trending, alarming, reporting, etc.

Communications in the SCADA System

There are two stages of communications in the SCADA-to-device path:

- between the display client and the I/O server
- between the I/O server and the PLC (or standalone system)

You may use multiple I/O servers to enable redundancy.

I/O Server to Field Device Communications

Summary

The way a SCADA system gathers data from the field device can greatly affect network and device loads and overall system response times. Communications between the I/O server and the field devices can follow several common models. Most SCADA systems use a combination of:

- data exception reports from field devices
- I/O server polling for field status, based on user-configured groups and time periods
- I/O server exception writes in response to operator commands
- I/O server time-based read/writes for tags used in application code

Exception Reporting

Exception reporting is the most efficient but least common method for transferring data between a field device and the SCADA system. The field device needs to be aware of the tags the SCADA system is using and needs to monitor these tags for changes in the field device. When a value in a tag changes, the field device writes the new value to the SCADA. For this method to work, the field devices needs to be able to initiate communications with the SCADA system (through a Modbus messaging client) and SCADA system must be able to receive the data transfer (through a Modbus messaging server).Exception reporting is used for reporting the status of field devices for display, trending, and alarms.

Exception reporting is efficient because the same unchanged values are not transferred over and over again (as they are in a polled system). This exception reporting system allows the device to close the TCP socket when data values are unchanged, thereby freeing up the TCP socket for other uses and reducing the device load.

Exception Reporting Problems

SCADA systems normally poll data from field devices to monitor the status of each device. The SCADA can detect and notify you of a communications failure. If the SCADA system is not polling the field device (as in an exception report system), it cannot detect or report a communications failure. To enable the SCADA system to detect a communications failure, it must either:

- expect write commands from the field device every *n* seconds
- poll the field device occasionally to check if it is on-line

An additional problem is that a write response from the field device can be lost or a value can change while the SCADA system is unable to receive the message. In this case, the SCADA system displays the old value but does not display a communications error. To correct this, the field device periodically transfers the tag value.

Field Device Monitoring

It is not practical for a field device to individually monitor a great number of variables to determine if an exception report is required. Most systems use a checksum on a group of variables. A backup write should always be implemented because the checksum can fail. For example, multiple variables may change in a way that makes the checksum stay the same. The field device can reduce device and network loads by applying hysteresis to the variables and sending an exception report only when a variable changes by a predetermined amount.

Variation on Exception Reporting

If you use a SCADA system that does not implement a Modbus messaging server or a field device that does not implement a Modbus messaging client, the SCADA system polls only the checksum or a single bit to indicate that one or more tags in a block of data has changed. When a change is detected, the SCADA polls the entire data set to obtain the new values. This system is not normally supported natively within the SCADA system. You must code it using some form of user logic within the SCADA system.

To poll for field status, the SCADA package reads data from each field device. Normally the SCADA package determines how the data is polled based on either:

- user-defined groups
- SCADA-created groups

If you set up the groups, you must take into account:

- how variables are grouped and their corresponding addresses in the field devices
- how often the groups are polled compared to the rate at which they are answered
- when the groups are polled: continually or as required
- how the polling of groups is linked

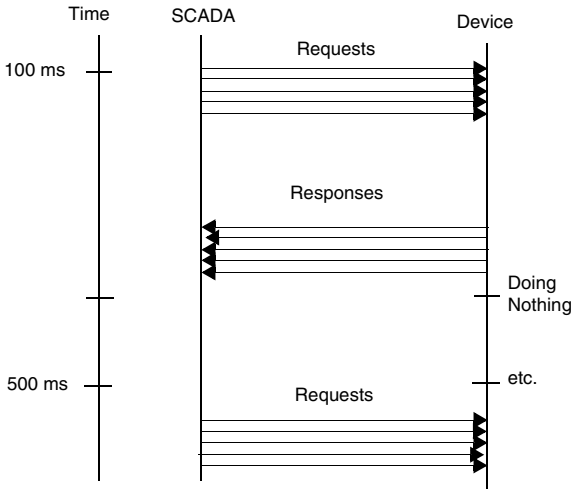
The groups of variables should be set up so they are polled at a rate no faster than that which the field device can answer. To calculate this rate, consult the system performance evaluation section (see *p. 319*). Remember to take into account all other devices, including other SCADA systems, that are communicating with the field device.

When creating groups, try to group tags so that the polling of the groups can be turned on and off. The variables are polled only when they are required. You may code this behavior or use an automatic feature of the SCADA system. In either case, the alarm variables need to be placed into one group and trending variables into one or more groups separate from the display variables. The group containing the display variables needs to be polled only when the tags are active on a screen.

When SCADA systems use an OPC server to read data from a field device, each I/O server may create separate groups (even though each I/O server is polling the same variables). The SCADA system may try to add/remove variables from the groups on the OPC server. This process is inefficient because of time delays.The preferred alternative is for the SCADA system to create a larger number of groups with fewer variables in each group and enable/disable the groups or variables within the groups. However, OPC servers vary in their abilities to enable/disable variables and groups or add remove variables from a group. OPC servers may or may not be able to block data for requests when the data is in multiple groups.

When the timing is set up for the polling of groups, make sure that the polling does not overload the field devices. The most common method used to poll data is to set a polling period that each group uses to read data. If this period is set to 1000, the group tries to poll all the data every 1000 ms. A problem can occur when multiple groups are set at the same polling rate. When the 1000 ms time expires, the SCADA system tries to read several blocks of data from the field devices, causing spikes in the network and field device loads. After these requests are answered, the field device waits passively until the next time it is polled. Depending on the field device, this overload may cause communication failure or delays.

If the device is able to buffer requests and answer them over time and if the total average load is less than the device capabilities, then the only problem is the small delay in answering the request.



To avoid this type of communications overload, set the polling periods of the groups to unique values. These values should be chosen so that the polling of multiple groups does not occur too often (e.g., 500 ms, 700 ms, 900 ms). A better solution is to link the polling of the groups. Link the polling so that one group has to finish before another group can be polled. This solution prevents:

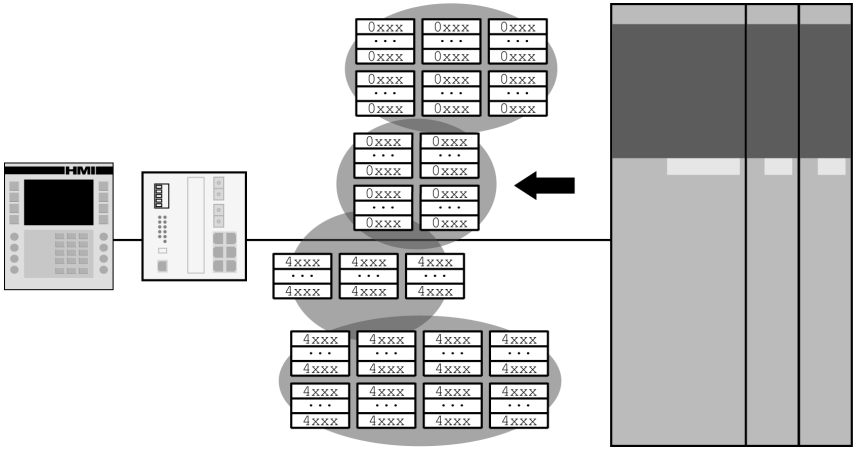
- an overload of requests that are waiting to be answered by the field devices resulting in communications failure
- a queue of requests forming in the SCADA system or field device

Some SCADA systems automatically link the polling of groups. Others require you to manually implement this function.

Blocking

For reading or writing the same type of data (the same Modbus function code), the SCADA system may try to combine multiple tags into a single data transfer for efficiency. This is not normally done for write commands, except when you are writing tables of data.

The way a SCADA system combines values into a single read is known as *blocking*. Blocking can improve the efficiency of the overall system communications.



For blocking to be most efficient, the variables in the field device should be located so that all the data required by the SCADA system is together in the Modbus memory area. When defining groups that the SCADA system polls, arrange the variables inside the field device so that all variables within a group are adjacent to each other. Even if you are not arranging the groups to be polled, arrange the variables used for alarms and trending so they are adjacent to each other. Items that are trended at the same rate should be grouped, and alarms should be grouped.

An exception to the data-blocking rule is unlocated variables. Both the Unity and Concept software allow variables in the field device to exist without physical addresses. A specific Modbus messaging function code can read/write these variables. The variables cannot be located next to each other, but the SCADA system can read/write them as efficiently as a block of located variables. However, some devices are able to answer requests for located variables faster or more often than for unlocated ones.

SCADA Communications to Field Devices: Socket and Request Usage

Summary

You need to consider several factors to determine how your SCADA system may transfer data to a field device:

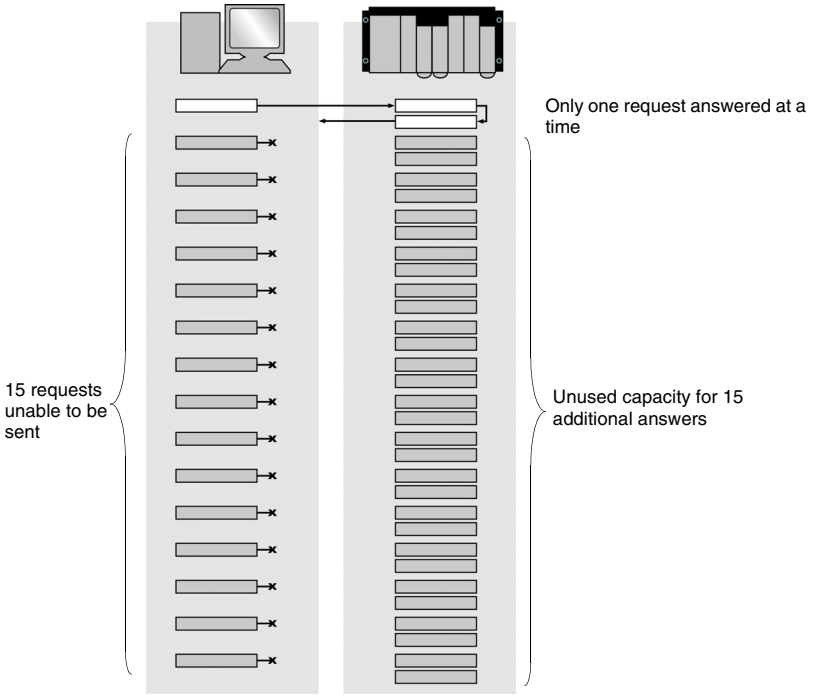
- how the data groups are structured
- when another section attempts to read the data groups
- TCP sockets and how they are used
- the number of Modbus messaging requests that can be sent down each socket
- the types of requests used

A SCADA system can open one or more TCP sockets to a device. It can send Modbus messaging requests on each of these sockets. Depending on how the SCADA system is designed, it may allow you to control the number of sockets to be opened and how the requests can be sent, or it may only perform as designed with no customizing possible.

Typical SCADA systems use a combination of 3 methods, with several sockets in use and one or more requests on each socket. Commonly one or more sockets are set up for reading and writing data. A request queue can form in both the end device and the SCADA system.

One Request at a Time

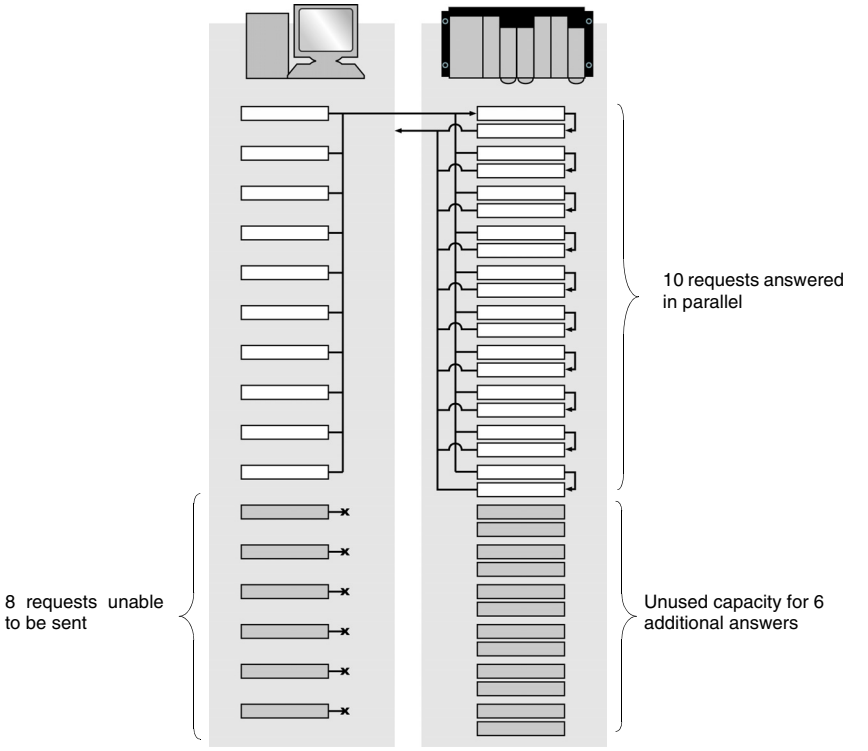
The efficiency of the SCADA system in sending requests and processing responses has a large impact on the system response time. Here is an example of a single socket that supports one request at a time:



The SCADA system only opens a single socket to the field device and is able to send only a single request. It waits until this request is answered before the next request is sent. This prevents overload in the end device by limiting the system to only one request at a time in the end device. It also severely affects system response time. For example, if the SCADA system has 10 requests to send to the end device, the end device takes 100 ms to answer each request and an additional 50 ms to send the new request. The overall time to answer all requests is 1.5 s.

Multiple Requests on a Single Socket

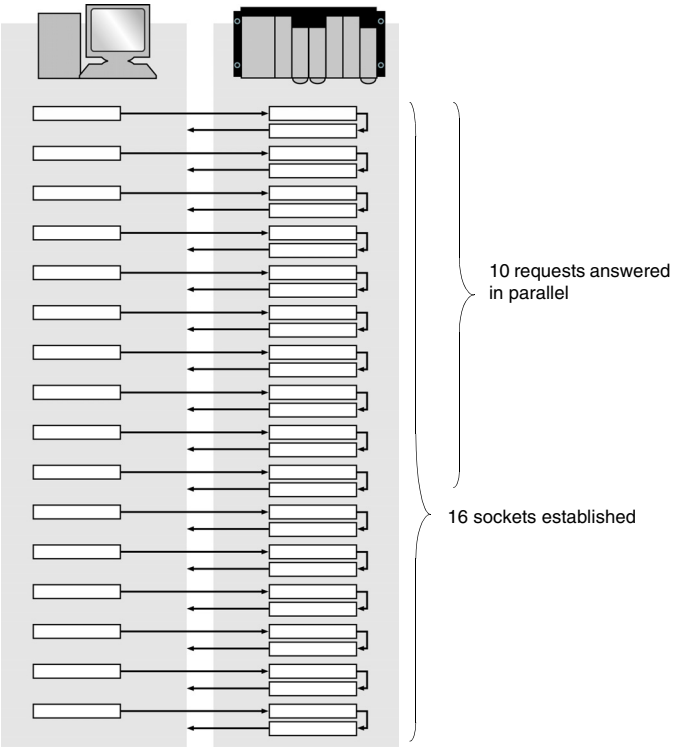
Here is an example of a single socket that supports multiple requests, in this case 10:



The SCADA system opens a single socket to the field device but is able to send 10 requests to the end device without waiting for an answer. The end device can start answering all 10 requests without delay. This system provides a faster response time, but can also overload an end device if the device cannot handle 10 requests at once. Even if the device can handle the 10 requests, it may not be able to handle more than one request at a time on a single TCP socket. This is common in older devices or devices that do not use the Modbus TCP transaction ID. The response time of the system is 150 ms, instead of 1.5 s as in the previous example.

Multiple Sockets Sending One Request at a Time

Here is an example of a SCADA system that uses 10 separate sockets to send requests to the field device but only sends a single request down each socket. This system handles devices support only a single request per socket.



This system avoids problems with devices that are unable to handle multiple requests on the same socket, but the end device may still become overloaded due to the total number of requests. The system response time is 150 ms.

I/O Server and Display Client Communications

Client communications between an I/O server and a display are commonly based on one or more of the following:

- proprietary systems and protocols
- OPC client/server communications
- MS Windows communications

Because most SCADA-to-SCADA communications rely on some form of MS Windows networking service (Com/DCom, machine names, etc.), this service must be installed on the network. However, by installing this type of service, the network becomes loaded down with additional MS Windows traffic and is susceptible to overloads by MS Windows and other traffic.

SCADA-to-SCADA communications should be separated from the normal device communications network whenever possible. You can do this by installing separate Ethernet cards into the SCADA PCs and running a separate Ethernet network for SCADA-to-SCADA communications.

Schneider Product Implementation Details

VijeoLook Implementation

VijeoLook uses the Schneider OPC server for communications (see *p. 257*).

Monitor Pro Implementation

Monitor Pro supports the I/O server/multiple clients model. When using the Modbus TCP/IP communications system, Monitor Pro implements user-defined groups, allowing you to configure the tags to be read in each group. You can trigger the reading and writing of each group via a user-defined tag. It can be a time-based tag for reads or a customized tag. For writes, the tag is automatically set whenever an item in the group is changed and only that item is written. For reads, the entire group is read. Groups can be sequenced by preventing the control tag for one group from being triggered before the completion flag is set for the previous group.

Monitor Pro uses a TCP socket for reads, a separate socket for writes, and another separate socket for exception reads. Each socket allows a single Modbus messaging request to be outstanding on the device at a time.

You can create an additional instance of the Modbus communications task and spread the variables to be read between the two tasks. Because additional requests can be sent to the field device at the same time, system performance is faster.

Monitor Pro creates a queue inside itself for any communications requests that are triggered but cannot be sent to the PLC because of outstanding requests on a socket. These requests go into the Modbus TCP/IP task mailbox. The mailbox can eventually overflow and cause communications to cease.

3.14 Redundancy

At a Glance

Overview

This section covers service redundancy from a system perspective. Total system redundancy is affected by the network, the devices, and the service redundancies.

What's in this Section?

This section contains the following topics:

Topic	Page
Network Redundancy and Communication Services	288
Redundancy within a SCADA System	292
SCADA in a Quantum Hot-Standby System	295
Hot Standby Swap and Ethernet Services	302

Network Redundancy and Communication Services

Summary

Redundancy allows the network to continue to carry data in the event of the failure of a network component or cable. When a failure occurs, some amount of time elapses before the failure is realized and corrected by the network components. This correction may or may not occur before other systems notice the problem.

Data being carried across the network may or may not be lost during the failure. If data is lost, it must be retransmitted.

If the network can recover before the time-out time for a service and if no data is lost during the break/recovery, the services are not affected. If the network cannot recover before the service time-out time, the service abandons the individual request. The service may or may not retry the transfer (depending on the service), but you will experience some delay in the information transfer. If the service implements retries, you do not notice an application error because the service is able to pass the data sent before the application error.

If the network cannot recover before the retry/time-out times, the service registers an error to the application. You need to decide if the application can tolerate service time-outs and errors or if the network should recover before a service time-out or error occurs. Be aware of the service time-outs and retry times before selecting a network redundancy strategy. A faster network recovery time is generally more expensive and it may not be needed in your application.

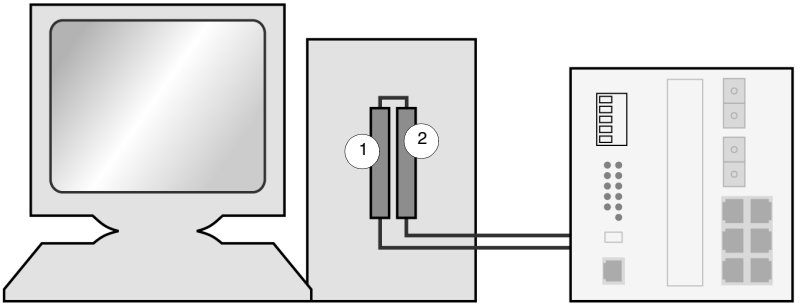
Multiple Ethernet Interfaces in a Device

Multiple Ethernet interfaces in a device are resilient when one of the Ethernet interfaces fails or when the attached network fails. However, they also require the communications to and from the device to be managed so all other devices can communicate to the active interface. If two Ethernet interfaces are installed in a device, there are two methods for handling communications: two linked interfaces or two independent interfaces.

Linked Interfaces

Two linked interfaces share the same IP address, and they appear to be a single Ethernet interface to the rest of the devices on the network. The two interfaces automatically monitor their ability to communicate with the rest of the system and decide which one is available to the device and the outside network. Enabling this solution requires no extra work.

Linked interfaces are commonly found in PC systems. They are similar to Modbus Plus redundant ports in that you do not need to act to benefit from the two interfaces. The interfaces monitor themselves and decide which interface to present to the outside network and to the device (so they see only one interface). Several Ethernet cards for PCs provide this functionality and their use is recommended.



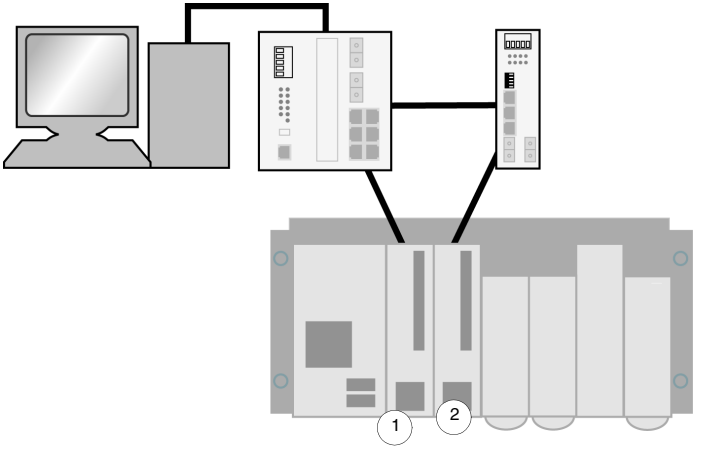
1 Interface 1 provides a single presentation to the SCADA and the PLC; it monitors the health of interface 2 to be sure that interface 2 can take over if it should fail.

2 Device 2 monitors the status of interface 1 and shares the same IP address as interface 1. It does not present information to the SCADA and PLC unless interface 1 fails.

Independent Interfaces

Each interface has a different IP address; only one interface is active at a time. This method of implementing multiple interfaces normally requires that you monitor the health of the interfaces within their application and decide which interface should be active. For example, with a SCADA package that has two unlinked Ethernet cards installed in a PC, the system monitors both interfaces and chooses one. Another example is that of two ETY modules in a Premium PLC. All Schneider Automation devices use this method.

You need to monitor the health of each interface and decide how to handle communications so that exchanges are not duplicated. Monitoring can reduce network traffic and load on other devices, but controlling communications in this way may not always be possible. If both interfaces need to be active (for global data, for instance), both interfaces process exchanges and pass the results to the device/application; the application must decide which information to use. Here is a Premium PLC with two Ethernet ETY communications modules:

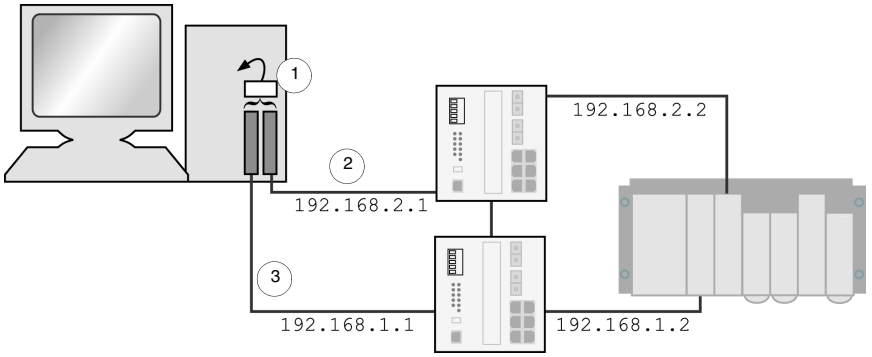


1 Interface 1 has its own IP address and appears as an independent device on the network
2 Interface 2 also has its own IP address and appears as an independent device on the network

In systems like the one shown above, you may be unable to control how communications are issued from each device because you cannot control which interface is used. This is a common problem for PCs configured with two Ethernet cards. The PC chooses a card to send data to based on the network on which the card is connected (as defined by the IP address and the subnet mask). The PC attempts to send requests through the card connected directly to the destination network. If a PC is configured with two Ethernet interfaces that have different IP addresses on the same network, the PC does not know which card to use. As a result, communications are erratic and can fail.

To avoid this problem, configure each Ethernet card for a separate network address range and manually control communications by addressing the communications to one network or the other. Unfortunately, the two Ethernet cards using different IP networks (even if they are connected to the same physical network) cause problems communicating with remote devices. The devices may not be able to communicate on both networks at the same time. Two complete networks must be constructed, and all the devices must be connected to both networks. You must determine which network is active through network management.

The following illustration shows a PC with two Ethernet cards going to the same switch and a PLC with two ETY modules connected to the switch.



1 A decision block inside the SCADA or PC program
2 Network B
3 Network A

Two independent networks supply a high level of redundancy, but a decision block must be included in the SCADA or PC program to determine which network to use at any given time.

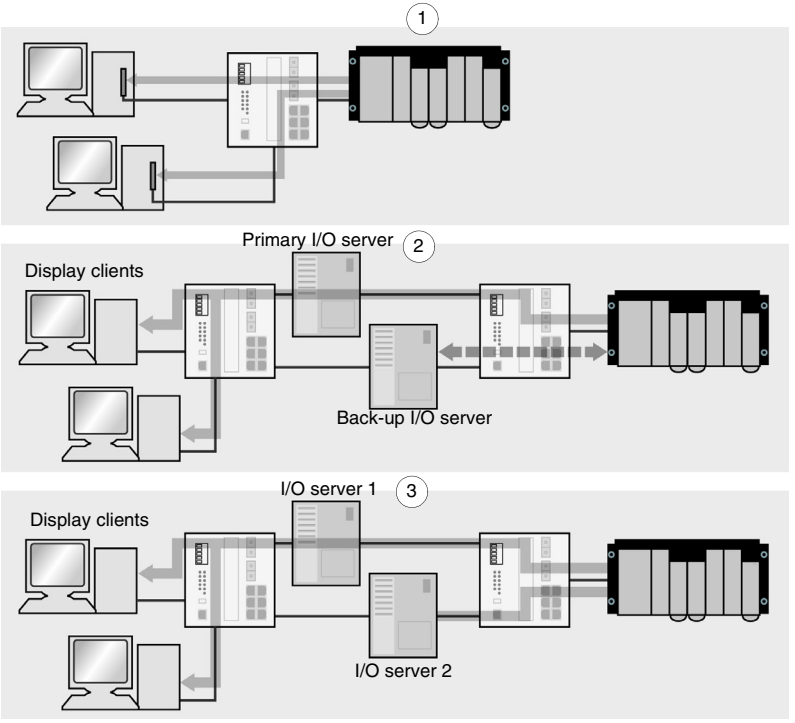
Redundancy within a SCADA System

Summary

Multiple levels of redundancy are available within a SCADA system. For plant communications, the SCADA system should operate so that only the primary I/O server exchanges data with the field devices. This provides the following benefits:

- greatly reduced communications load on the field devices, resulting in faster response times for the entire system
- reduced network traffic at the interdevice level of the plant.
- more efficient network traffic as the SCADA server-to-client traffic can be optimized (to transfer all data to a client instead of the client gathering information from each field device); traffic can be separated onto another network instead of the plant control network

The following illustration shows three completely redundant SCADA systems, all polling the PLC:



1 Two separate SCADA systems, both polling the PLC

2 Two display clients polling a primary I/O server. The back-up I/O server only monitors the health of the connections to the PLC

3 Two display clients polling an I/O server, where the I/O server does not know that there is redundant back-up. It continues to poll all data from the PLC.

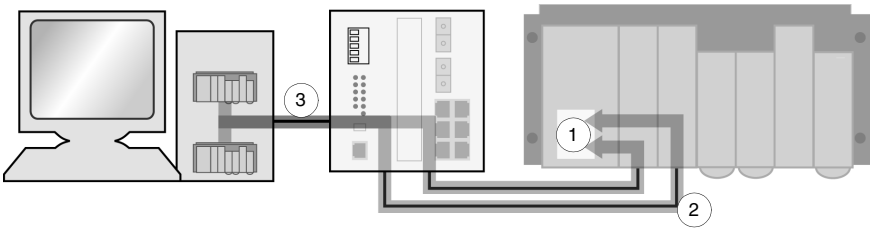
SCADA Communication to a Redundant Device

SCADA system planners need to consider redundancy from communications to redundant devices. For a redundant device to communicate, the SCADA system must be able to exchange the same data with what it considers to be two devices. For example, a Quantum PLC system that contains two NOE modules allows the SCADA system to exchange data with the PLC CPU using either NOE module. If one module fails (or the network attached to this module fails), communications continue using the other NOE module.

The SCADA system may be able to automatically manage communications to redundant devices or you may need to manage communications manually. For automatic management within the SCADA, you need only to enable the service and configure the SCADA system to recognize that the two devices are the same. If this support is not native to the SCADA, you must perform additional configuration and programming to make the system communicate to the devices on both interfaces.

The most common problem is that the SCADA system is configured to communicate to the Ethernet interface of the end device, not to the end device itself. The SCADA system should view a Quantum PLC with two NOE modules (e.g., IP address 192.168.1.10 and 192.168.1.11) as two separate devices, even though the SCADA requests are exchanged with the same CPU.

The following illustration shows a SCADA system communicating to a PLC with two Ethernet interfaces. The SCADA assumes that there are two PLCs, and it must decide the one with which it will communicate.



1 Data for both exchanges comes from the same variables in the PLC.
2 The PLC has two interface modules.
3 Two sets of data are exchanged.

The SCADA system needs to be able to retrieve the values it needs to display from one device or the other without affecting the final display of data. If the path to one device is unavailable, use the path to the alternate device or backup until the original path is available.

SCADA Back-up Watchdogs

A back-up device configured in a SCADA system is beneficial only when the system can reliably change over to the backup device if the primary device fails. The back-up device must be continually monitored to make sure it is operational; data from the back-up device needs to be read periodically so that the SCADA knows the health of the back-up at all times. Monitoring helps by:

- alarming a back-up failure while the primary is in use so the failure can be corrected before the back-up is required
- allowing the SCADA system to check the status of the backup before deciding to switch over

If the primary fails and the SCADA system switches to a failed standby, it may cause confusion among personnel, as well as waste time and stop your application.

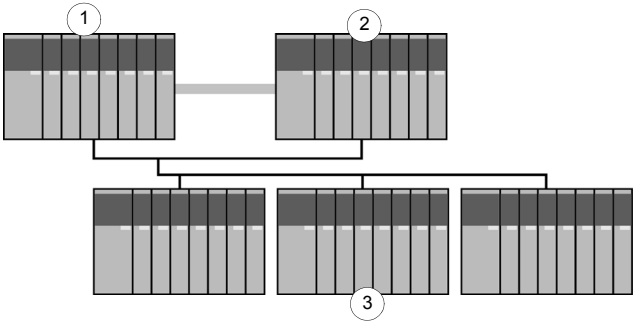
SCADA in a Quantum Hot-Standby System

Summary

Hot standby systems were traditionally implemented to control critical remote I/O in industrial automation environments. As SCADA systems continue to develop and play a more important role in plant operation, the role of a hot standby system has changed. A hot standby system may be required to provide redundant operation of control networks and SCADA communications. New hot standby control rules need to be defined.

Traditional Hot Standby System

In a traditional industrial automation system, the single goal of a hot standby PLC was to control the plant via physically connected I/O:



1 The primary CPU
2 The standby CPU
3 Racks of remote I/O modules

Hot standby provides redundant control of a plant via physical I/O. The system changes from the primary CPU to a standby CPU if the primary unit is unable to control the physical I/O. This can occur due to the failure of the primary system's:

- power supply
- CPU
- RIO adapter
- RIO link

A traditional hot standby system does not switch control from the primary to standby for any of the following reasons:

- failure of Modbus Plus or Ethernet links
- inability of the primary system to communicate to a remote device via a network link (other than I/O via the RIO network)

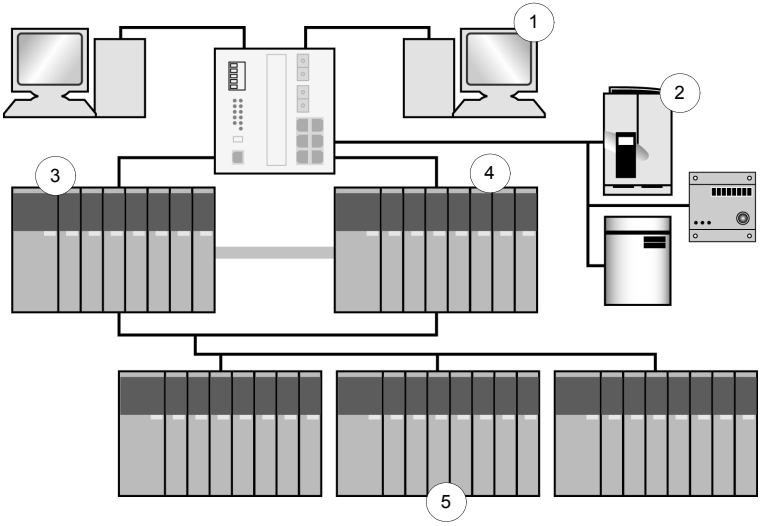
These restrictions present problems for a system that relies on SCADA system communications or plant control via network communications. In the event of a communications failure of the primary PLC, the system does not automatically switch over to the standby unit to re-establish communications, even if each PLC is capable of controlling the I/O.

Communication-centric Systems

In a communication-centric system, the integrity of the communications between the hot standby system and a device in the plant system may be important enough to justify a hot standby changeover. In this type of system, the standard Quantum hot standby operation must be modified so that the communications to the remote device are monitored and a changeover is forced if communications fail.

Note: You may implement a hot standby system for communications purposes only. Such a system is not required to control physical plant I/O. A dummy I/O rack must be configured, and the RIO network needs to be physically installed to allow the hot standby system to operate.

The following illustration shows a redundant SCADA system with hot standby PLCs.



1 SCADA monitoring a critical process controlled by the PLC
2 Critical intelligent devices controlled via Ethernet by the PLC
3 The primary CPU
4 The standby CPU
5 Racks of remote I/O modules

The original industrial automation priorities of the hot standby system, which provide redundancy for the remote I/O, remain the same. In addition, you can assign equal (or even greater) hot standby priority to the plant's communication link.

Although the Quantum hot standby system was originally designed principally for I/O control, full user control of the changeover capability is provided. You can customize the operation so that communications failures at the plant level trigger a primary-standby changeover. You can program your system to switch control if the current primary CPU loses communications with the SCADA platforms or with the critical Ethernet devices, even if there are no communication problems between the CPU and the remote I/O.

Rules for a Communication-centric Hot Standby System

The following questions must be answered to enable a communications based HSBY system to be implemented:

- What communication links must be monitored?
  In the event of a failure, should the links cause a changeover of the hot standby PLCs?
- What defines a communication failure (time-outs, retries, etc.)?
- Will redundant Ethernet interfaces be implemented?
  If so, how will they be addressed?
- How will the health of the communications network on the Standby PLC be monitored to be sure that a changeover improves communications?

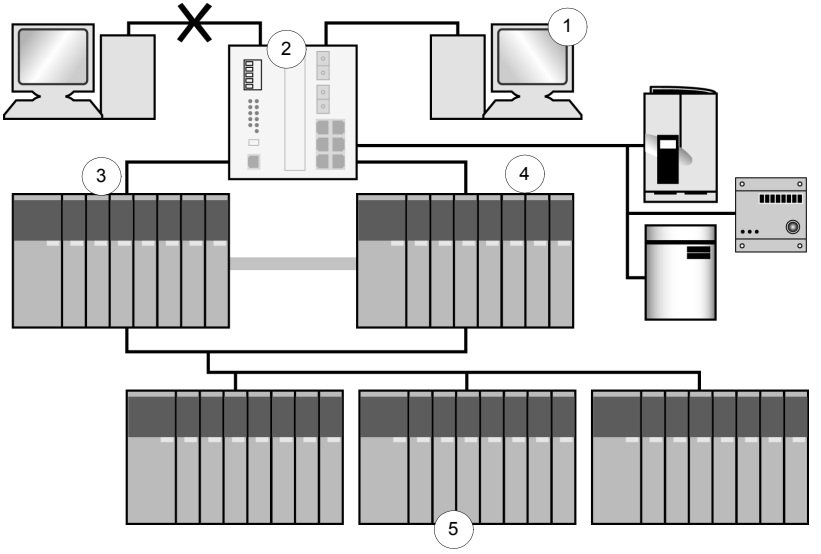
Basic Redundant System

To achieve basic communications redundancy for a minimum investment in extra hardware and time, the system should have:

- a single network connection to each PLC in the hot standby system
- network connections monitored using the module diagnostics functions

Basic Redundancy System Limitations

Changeover can be set up to occur if the primary CPU cannot locate a SCADA platform or if the connection between the CPU and the Ethernet switch fails. However, hot standby PLCs cannot detect a communications failure due to a break in the network beyond their local connection.

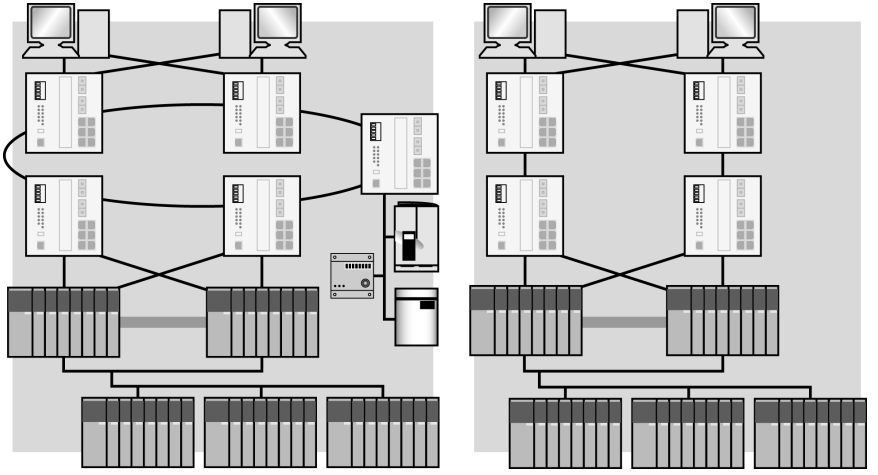


1 SCADA monitoring a critical process controlled by the PLC
2 Ethernet switch
3 The primary CPU
4 The standby CPU
5 Racks of remote I/O modules

The failure of a single critical device beyond the local connections can cause the failure of the entire communications system as shown in the illustration above.

Fully Redundant System

A fully redundant system must be implemented when the specification calls for *no single point of failure* for the control system, including communications.



1 Redundant SCADA system with dual linked Ethernet interfaces
2 Switch-based network with spanning tree
3 ConneXium redundant ring network
4 Hot standby PLC system with dual independent Ethernet interfaces

A fully redundant system typically uses the following:

- additional network hardware installed for redundant network paths
- each PLC in the hot standby system connected to a separate network path
- each PLC connected to the network at multiple points using multiple network cards in the PLC (for a network or network card failure that does not trigger a changeover)
- communications paths monitored by watchdogs for communications integrity along the entire path to the end devices
- other devices (such as the SCADA system) connected to the network at multiple points using multiple network cards
- optionally, a complete second physical network
- each connection point (switch or a hub) for a device (e.g., PLC, SCADA system, etc.) powered from a separate power supply so that the failure of a single power supply does not disconnect the device from the network

Fully Redundant System Limitations

Fully redundant systems have the following limitations:

- increased cost of components
- the need to modify systems outside of the hot standby PLC
- system complexity

Network Monitoring via Module Status

The status of the local Ethernet communications module can be monitored by the PLC program using the MSTR or MBP_MSTR block to read local statistics. These blocks provide information on the health of the module and of the Ethernet link from the module to the first hub or switch.

Word 3 of the returned data is defined as the board status.

Bit #	Definition
15...12	Module type
11	(Reserved)
10	0 = half duplex 1 = full duplex
9	0 = not configured 1 = configured
8	0 = PLC not running 1 = PLC/NOE running
7	0 = Link LED off 1 = = Link LED on
6	0 = Appl LED off 1 = Appl LED on
5	0 = twisted pair 1 = fiber
4	0 = 10 Mbit 1 = 100 Mbit
3...0	(Reserved)

Bit 7 (Link LED on) can be monitored to determine the status of the connection from the module to the local hub or switch. If the Ethernet module is faulty, an error is returned by the Read Local Statistics command.

Note: The Read Local Statistics command monitors only the local connection. It does not ensure that the full network required to communicate to a remote device (such as additional hubs or switches that are used to connect to the other device) is intact. It does not check the operation of the remote device. Device monitoring by watchdogs is a more reliable way to determine the health of communications to a remote device.

Device Monitoring via Watchdogs

To completely monitor the operation of a remote device and the connection to it, a watchdog should be implemented. To implement a watchdog from a SCADA system to a PLC, send a single write register from the SCADA system to a register in the PLC. The PLC increments this register, the SCADA reads the new value back, increments the value again, and writes the value. The cycle runs constantly.

The watchdog monitors the operations of the full network link between the two devices and the operations of the PLC and the SCADA systems. It informs both devices of a device or network failure. A simpler watchdog can be implemented by having the PLC read a value from a remote device or by reading a value that changes in a known way (such as a counter) from the remote device. These two methods check the network link, but do not enable the remote device to know the PLC status.

Note: When implementing watchdogs via a register that is incremented, be sure to account for the situation when the register rolls over (e.g., from 32767 to 0).

Standby Unit Monitoring

When implementing a hot standby system where communication links are monitored and where a failed link may trigger a changeover, you need to know the status of the standby link. All nonoperational links should be monitored (back-up links on primary and all links on the standby PLC) to detect and correct link failure before the link is needed.

The standby link status should also be known so the PLC can determine if the changeover re-establishes communications. If communications are not re-established, the changeover will not improve plant control redundancy. Also, a changeover can affect other devices.

The standby communication links in the primary PLC are monitored in the same way as the primary link. They can be monitored with a `Read Local Statistics` command or with a full watchdog. A full watchdog for the standby PLC is different from a watchdog on the primary PLC because the standby PLC is not always processing code.

Use the reverse transfer registers of the hot standby system to transfer the register written by the SCADA system to the primary PLC and increment the register there. Then transfer the register either back to the SCADA system using the primary PLC's communication links or back to the standby PLC using the hot standby link where the SCADA system reads the result. Current Quantum hot standby systems allow a small amount of code to be executed in the standby PLC. The code can be used to execute the `Read Local Statistics` command and place the results in the reverse transfer registers for transfer to the primary PLC.

PLC IP Addresses

In a Quantum hot standby system, the IP address of the Ethernet modules in the standby rack is automatically set to the IP address of the Ethernet module in the primary rack plus one. For example, if the NOE module in primary rack is address 192.168.1.10 then the NOE in the standby rack is 192.168.1.11. When the system performs a changeover, the IP addresses of the Ethernet modules also swap. This simplifies communication programming for other devices since they can always communicate to a single IP address. This feature is available with the exec version 2.0 or greater of the NOE 77100/10 modules.

Manual Hot Standby PLC Changeovers

The PLC code in a Quantum PLC can initiate a hot standby system changeover with the Hot Standby control word. To cause a change from primary to standby, the primary PLC sets the bit to indicate that it is offline. After changeover, the new primary PLC can be used to set the original PLC back online. Since there is already a primary PLC running in the system, the original primary PLC comes back on line as the standby PLC.

Note: Manually setting the primary PLC offline to force a changeover works only if the standby unit is available and able to go online. Make sure the PLC code checks this using the hot standby status word before a change is initiated by the PLC code. Failure to do so may result in both PLCs going offline.

Common Problem (Hunting)

Hunting is the term used for a problem in a hot standby system implemented with multiple communications paths. It describes a situation where one device (e.g., the SCADA system) is attempting to communicate using one communications link (e.g., to the Standby PLC) to determine if that link is the correct one. The primary PLC waits for a good SCADA system communications watchdog. Since neither system is able to receive a valid communications watchdog, each attempts a new path. If both systems swap at the same time, they only continue to swap and never establish communications on the same link.

To avoid hunting:

- monitor all the active communications links for watchdogs, including the links in the Standby PLC.
- establish a clear system master such as the primary PLC. If the primary PLC sees communications to the SCADA system on both primary PLC links and standby PLC links, it does not change over. It waits for the SCADA system to establish communications on the correct link (in this case a link to the primary PLC).
- set different amounts of time for the SCADA system and the PLC to try a communications link. If the PLC is the system master, it should wait and monitor its current link for the amount of time required for the SCADA system to attempt communications on all the possible links. Only after this time should the PLC switch to another communications link.

Hot Standby Swap and Ethernet Services

Services Available

The following services are available in a hot standby system:

Service	Description
Modbus Client	Running in both primary and standby. Only the first section of PLC application is running in the standby to trigger Modbus client requests.
Modbus Server	Running in both primary and standby. Requests to the standby PLC are processed by the standby CPU; Modbus write data may be overwritten by the hot standby data transfer.
I/O Scanner	Running in primary, stopped in standby
Global Data	Running in primary; standby may send some maintenance messages at start-up but does not publish or subscribe to data
FTP/TFTP	Running in both primary and standby
SNMP	Running in both primary and standby
SMTP	Running in both primary and standby; e-mail messages in the standby can be triggered only in first section of PLC application (the only section running)
NTP	Running in both primary and standby; primary Ethernet communications module sets the clock in the primary CPU, standby Ethernet communications module sets the clock in the standby CPU. The NTP clock is not transferred between primary and standby CPUs.
Web (Embedded and FactoryCast)	Running in both primary and standby as independent services

Services not Available

The faulty device replacement service (see *p. 205*) is not available because the DHCP server is not available.

Changeover Operation

If there is a changeover from the primary to the standby PLC, the IP swapping function automatically assigns the IP address of the Ethernet communications module in the primary PLC to the Ethernet communications module in the standby PLC. The changeover is transparent to other network devices. After closing the current client/server and I/O scanner connections on Ethernet using a reset, each Ethernet communications module sends a UDP changeover message to the Ethernet communications module in the other PLC. The Ethernet communications module that sent the message waits for the response from the other Ethernet communications module or for a time-out of approximately 500 ms. As soon as the message is received or after the time-out, the IP address changes over.

During the changeover any Modbus messaging communications currently in progress (either client or server) are aborted and must be resent. Any MSTR or read/write blocks in the PLC application must be retriggered, and any remote requests (e.g., SCADA) must be resent by the remote device.

I/O scanning needs to re-establish the MAC address (using ARP requests) and socket connections to each remote device before data transfers resume. The time required depends on the time it takes the remote device to respond to the new socket-open request.

Note: Each line in the I/O scanner is an independent entry; each begins data transfers at different times. The IO scanner needs only the MAC address and socket for the device listed on a line before it starts communicating with the device. As a result, the I/O scanner starts to communicate with each device when each is ready, rather than waiting for all devices to be ready.

For global data service, the standby NOE leaves the global data group and the new primary joins the group and starts publishing. The time required for this is dependent on the implementation of multicast filtering (see *p. 136*) and the number of devices in the group (global data start-up times).

All other services force clients to disconnect (either by reset or time-out). Services are restarted on both the primary and standby Ethernet communications modules. As a result, services are unavailable for a short amount of time, but overall system operation is not affected. For example, the NTP service restarts, but the CPU clock remains accurate for the time required to restart the service. A Telnet session is disconnected, and you must reconnect.

The most recent versions of distributed I/O on Ethernet TCP/IP have a function for maintaining the status of the outputs when there is a break in communications (such as a hot standby changeover). Devices controlled by distributed I/O continue to operate during the changeover.

TCP Socket Numbers

In all cases, the TCP source sockets used on the new module and the old module should be different. Different sockets prevent confusion between the old and new connections to the remote device.

3.15 Gateway/Bridge Systems

At a Glance

Overview

This section describes gateway and bridge systems.

What's in this Section?

This section contains the following topics:

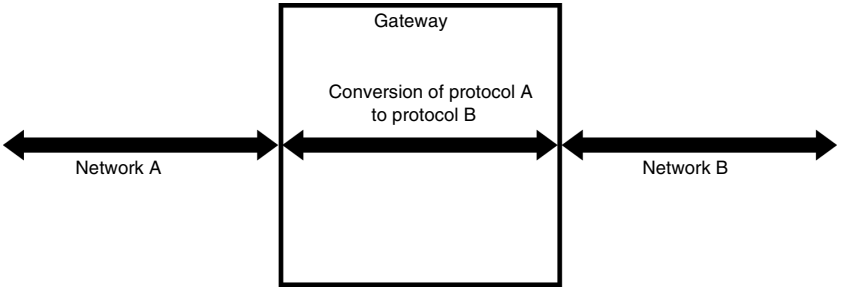
Topic	Page
Gateway and Bridge Overview	305
Gateway and Bridge Operation	309

Gateway and Bridge Overview

Summary

A gateway allows devices on one network to communicate with devices on a separate network by converting the protocol on one side to the protocol on the other. Gateways (also known as bridges) are used in an Ethernet system to convert from one type of network to another (e.g., coaxial Ethernet to twisted pair, token ring to Ethernet).

The following illustration shows protocol A on one side and B on the other with a message going from one side to the other.



Operation

Gateways can be grouped into 3 different types, based on how devices are enabled on the 2 connected networks to communicate, as follows:

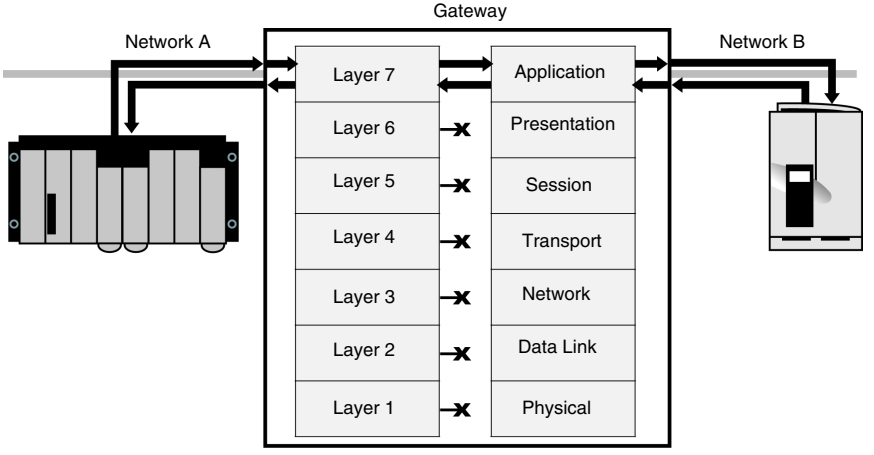
- gateway without protocol conversion
- gateway with protocol conversion
- gateway using shared memory (read and write)

Gateway without Application Protocol Conversion

A gateway without protocol conversion is able to take a message from the source network and pass the same message onto the destination network without modifying the application protocol. The gateway waits for a response, then passes this response back to the source network. This type of gateway is the most efficient and powerful implementation because no limits are put on the protocol. However, this gateway is possible only if both the source and destination networks use the same application-layer protocol. Schneider's Modbus Ethernet-to-Modbus serial and Modbus Ethernet-to-Modbus Plus gateways are examples of this gateway type.

Note: A minor modification of the application message is made in conversion from Modbus Ethernet to Modbus Plus or Modbus serial; a bridge index and transaction ID are included in a Modbus Ethernet packet, but these are not present at the applications layer for Modbus Plus or Modbus serial. On Modbus Plus, the bridge index is part of the addressing used by the lower layers. On Modbus serial, the index is not required. A transaction ID is not required on either system.

This type of gateway receives the packet containing the application layer message and removes the lower layers before passing the message to the destination network. Because the actual message is not interpreted, the total system response time can be lower, and you can use functions supported by both networks.

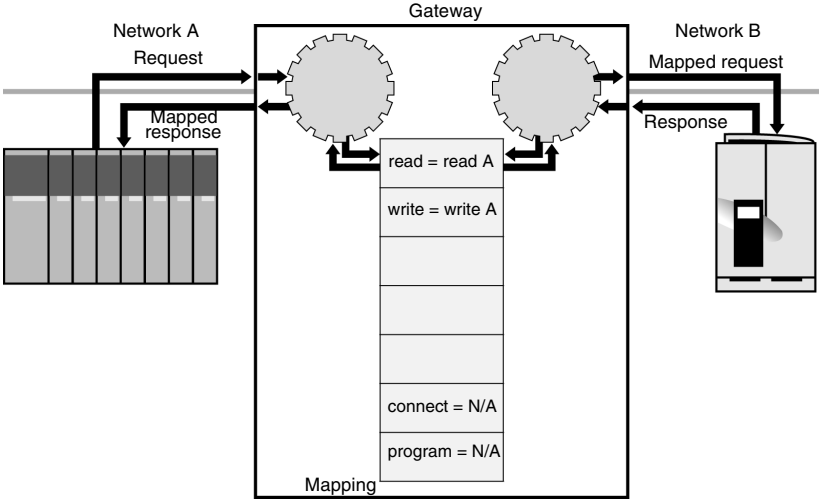


Gateway with Application Protocol Conversion

A gateway with protocol conversion takes a message from the source network, and converts it to the appropriate destination message format, and sends it to the destination network. The gateway then waits for a response and converts the response before sending it back to the source network. The gateway actually reads the application message from the source network, but refers to an internal table to find the message to be sent onto the destination network.

This conversion is required when the source and destination networks do not use the same application layer protocol. Gateways that use this system include those that connect Modbus networks to networks from other vendors. Because the message from the source network must be received and interpreted before an outgoing message is sent, this type of gateway is slower than a gateway that does not do application protocol conversion.

The rules for protocol conversion are based on rules defined by the gateway designer; only messages identified by the designer can be converted. Messages defined after the gateway is designed are not converted. You cannot normally modify the mapping of messages from one network to the other. This type of gateway is only able to map a simple message for which there is an equivalent on both networks. Messages with no equivalent on the other network cannot be mapped. As a result, it is not possible to program over this type of gateway.

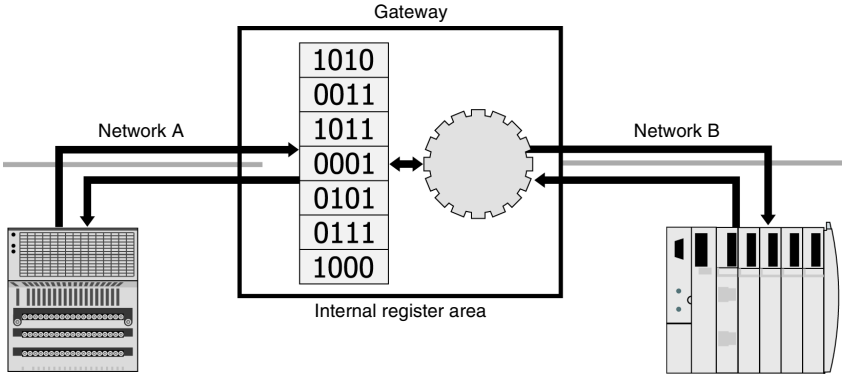


Gateways Using Shared Memory

Some gateways can present a shared memory area to devices on both networks. Devices on both networks can read or write data from this memory area and can share data although no message is actually passed from one network to the other. A device on the source network can write data to the shared memory area, and a device on the destination network can then read the data from that memory area.

A gateway of this type never actually passes a message from the source network to the destination network. No programming is required, and no complex messages are transferred. Only data using the memory types presented in the shared memory area can be transferred. For example, if only words are supported, the transfer of individual bits is not supported.

This gateway decouples the two networks. Because it does not wait for a response from the destination network before it responds to the request, this gateway can respond very quickly with data from its shared memory area. Although this gateway appears to be very fast, the actual response time is slow because all data must be handled twice, once into shared memory and once out to the other network. These two tasks are not synchronized, so system response time is slow and inconsistent.



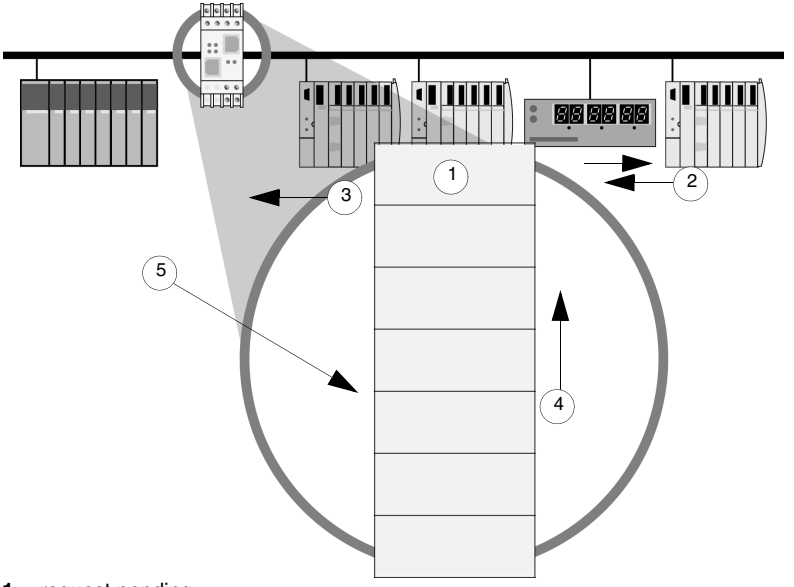
Gateway and Bridge Operation

Queues

If devices on the source network are sending requests to the gateway faster than they can be processed on the destination network, a message queue forms inside the gateway. Depending on the actual gateway, the queue may have a fixed maximum length. Once the queue is full, the gateway either crashes or returns a new message request with an error response.

Consider the response time of the destination network and the effect of a timeout as it pertains to the queues inside the gateway of the destination network. To help prevent a queue from growing to unreasonable lengths, requesting devices should not send a retry of a message before the gateway has processed the message; they must wait until either a response or error message is received before sending the retry. Devices must keep track of the number of messages sent to the gateway for which they have not received answers; this number needs to be kept low.

The queue affects the system response time. If a source device sends a command to the destination network device, the command must wait in the queue until all pending messages are sent before it can be processed. This can create slow system response times. The best response times are achieved when the queue is never empty and never longer than 1 or 2 messages.



1 request pending
2 response
3 response to client
4 all requests move up in the queue
5 a new request is placed at the end of the queue

Gateway Sockets

A gateway enables a large number of devices on one network to communicate with a large number of devices on another network. When a large number of devices connects to an Ethernet network gateway, a large number of TCP sockets must be opened. For low-cost gateways, the number of sockets is limited by the low processing power and low memory of the components chosen. Once the number of sockets is exceeded, no additional devices can connect to the gateway. Problems can be caused when:

- the requesting devices choose communications services that require a TCP socket for every device they communicate with
- services hold a socket open after communications have finished

Examples of these are the I/O scanner service and the Modbus client service on older devices. To reduce the number of sockets held open on a gateway, use the enable/disable function in the I/O scanner or Modbus client requests.

Gateway Timeouts

When a gateway sends a message onto the destination network, that message follows the timeout and retry timings of that network. However, the requesting device has sent a message to the gateway that is following the timeout and retry times of the source network.

If the total time for the timeout and retries on the destination network is longer than the timeout of the source network, the source network resends the request. Duplicate messages are placed in the queue. When Modbus TCP/IP is the source network, there is no application layer retry; as long as the gateway acknowledges the TCP packet, there is no retry on the source network. However, you may manually resend the same message.

If the first message in the queue is sent to a disconnected device, that message times out and is retried. All other messages in the queue are delayed and possibly timed out by the requesting device. If these messages do time out, the requesting device may resend the message, causing multiple messages in the queue. When the initial message is answered by the gateway, it is discarded by the requesting device, because this message has already been timed out.

To avoid this situation, the timeout for any messages sent from the source network needs to be set greater than:

timeout x *the number of retires on destination network* x *the maximum number of requests expected in the queue*

Avoid having this number become too long. Set the number of retries on the destination network to a low value and do not send request to devices that are known to be unavailable. If a device is normally polled every 5 s but has returned 2 errors in a row, check that device only once every 30 seconds to see if it is able to respond again.

Response Times

Response times for Schneider Gateway systems are shown in Appendix A (see *p. 371*).

Common Problems

Common problems with gateway systems include:

- overloaded gateways caused by source network devices sending requests faster than they can be processed on the destination network
- communications errors to one or all destination devices when a single-destination device is removed; caused by time-outs that affect how quickly communications are processed on the destination network and produce overloads
- timed-out requests from the source device before the message is processed on the destination network; caused by setting incorrect time-out values or by a failure to consider the effect of message queuing in the gateway
- inability to connect to the gateway because all the socket connections are in use

3.16 Supported Services per Device

Ethernet Services and the Transparent Ready Devices that Support Them

Quantum Devices

The following table lists the Ethernet services supported by the Quantum CPUs with embedded Ethernet ports and by the Quantum Ethernet communications modules:

Service	140CPU65150	140CPU65160	140NOE77101	140NOE77111	140NWM10000
I/O Scanner	X	X	X	X	-
Modbus Server	X	X	X	X	X
Modbus Client	X	X	X	X	X
Global Data	X	X	X	X	-
FDR Server	X	X	X	X	-
FDR Client	-	-	-	-	-
BootP Client	X	X	X	X	X
Time Synchronization	-	-	-	X	-
E-mail Notification	X	X	X	X	X
Web/Embedded Diagnostics	X	X	X	X	X
FactoryCast Web Server	-	-	-	X	X
FactoryCast HMI Web Server	-	-	-	-	X
SNMP	X	X	X	X	X
FTP Server	X	X	X	X	X
TFTP Server	X	X	X	X	-
Telnet Server	X[1]	X[1]	X[1]	X[1]	X[1]

[1] For factory diagnostic purposes only.

Premium CPUs

The following table lists the Ethernet services supported by the Premium CPUs with embedded Ethernet ports:

Service	TSXP571634M	TSXP572634M	TSXP573634M	TSXP574634M	TSXP575634M
I/O Scanner	X	X	X	X	X
Modbus Server	X	X	X	X	X
Modbus Client	X	X	X	X	X
Global Data	X	X	X	X	X
FDR Server	X	X	X	X	X
FDR Client	-	-	-	-	-

Service	TSXP571634M	TSXP572634M	TSXP573634M	TSXP574634M	TSXP575634M
BootP Client	X	X	X	X	X
Time Synchronization	-	-	-	-	-
E-mail Notification	X	X	X	X	X
Web/Embedded Diagnostics	X	X	X	X	X
FactoryCast Web Server	-	-	-	-	-
SNMP	X	X	X	X	X
FTP Server	X	X	X	X	X
TFTP Server	X	X	X	X	X
Telnet Server	X[1]	X[1]	X[1]	X[1]	X[1]
[1] For factory diagnostic purposes only.					

Premium Ethernet Communications Modules

The following table lists the Ethernet services supported by the Premium Ethernet communications modules:

Service	TSXETY4103	TSXETY110WS	TSXETY5103	TSXWMY100
I/O Scanner	X	-	X	-
Modbus Server	X	X	X	X
Modbus Client	X	X	X	X
Global Data	X	-	X	-
FDR Server	X	-	X	-
FDR Client	-	-	-	-
BootP Client	X	X	X	X
Time Synchronization	-	-	X	-
E-mail Notification	X	-	X	X
Web/Embedded Diagnostics	X	X	X	X
FactoryCast Web Server	-	X	X	X
FactoryCast HMI Web Server	-	-	-	X
SNMP	X	X	X	X
FTP Server	X	X	X	X
TFTP Server	X	-	X	-
Telnet Server	X[1]	X[2]	X[2]	X[1]
[1] For factory diagnostic purposes only.				

TSX Micro Ethernet Communications Modules

The following table lists the Ethernet services supported by the TSX Micro Ethernet communications modules:

Service	TSXETZ410	TSXETZ510
I/O Scanner	**-**	**-**
Modbus Server	X	X
Modbus Client	X	X
Global Data	-	-
FDR Server	-	-
FDR Client	X	X
BootP Client	X	X
Time Synchronization	-	-
E-mail Notification	-	-
Web/Embedded Diagnostics	X	X
FactoryCast Web Server	-	X
SNMP	X	X
FTP Server	X	X
TFTP Server	-	-
Telnet Server	X[1]	X[1]
[1] For factory diagnostic purposes only.		

Momentum M1E Processors

The following table lists the Ethernet services supported by the Momentum M1E CPU modules:

Service	171CCC96020	171CCC96030	171CCC98020	171CCC98030
I/O Scanner	X	X	X	X
Modbus Server	X	X	X	X
Modbus Client	X	X	X	X
Global Data	-	-	-	-
FDR Server	-	-	-	-
FDR Client	-	-	-	-
BootP Client	X	X	X	X
Time Synchronization	-	-	-	-
E-mail Notification	-	-	-	-
Web/Embedded Diagnostics	X	X	X	X

Service	171CCC96020	171CCC96030	171CCC98020	171CCC98030
FactoryCast Web Server	-	-	-	-
SNMP	-	-	-	-
FTP Server	-	-	-	-
TFTP Server	-	-	-	-

Momentum Ethernet Communications Modules

The following table lists the Ethernet services supported by the Momentum Ethernet communications modules:

Service	170ENT11001	170ENT11002
I/O Scanner	**-**	**-**
Modbus Server	X	X
Modbus Client	-	-
Global Data	-	-
FDR Server	-	-
FDR Client	X	-
BootP Client	X	X
Time Synchronization	-	-
E-mail Notification	-	-
Web/Embedded Diagnostics	X	-
FactoryCast Web Server	-	-
SNMP	X	-
FTP Server	X	-
TFTP Server	-	-
Telnet Server	X[1]	-
[1] For factory diagnostic purposes only.		

Twido Devices

The following table lists the Ethernet services supported by a Twido CPU and a Twido Ethernet communications modules:

Service	TwidoPort 499TWD01100
I/O Scanner	-
Modbus Server	X[1]
Modbus Client	X[1]
Global Data	-

Service	TwidoPort 499TWD01100
FDR Server	-
FDR Client	-
BootP Client	X
Time Synchronization	-
E-mail Notification	-
Web/Embedded Diagnostics	-
FactoryCast Web Server	-
SNMP	-
FTP Server	X
TFTP Server	-
Telnet Server	X
[1] Device receives and sends Modbus messages as a gateway.	

Advantys STB Distributed I/O

The following table lists the Ethernet service supported by an Advantys STB standard Ethernet network interface module (NIM):

Service	STBNIP2212
I/O Scanner	-
Modbus Server	X
Modbus Client	-
Global Data	-
FDR Server	-
FDR Client	X
BootP Client	X
Time Synchronization	-
E-mail Notification	-
Web/Embedded Diagnostics	X
FactoryCast Web Server	-
SNMP	X
FTP Server	X
TFTP Server	-
Telnet Server	-
[1] Device can be scanned by the I/O scanner as it implements the Modbus server.	

Altivar ATV 38/58 Variable Speed Drive

The following table lists the Ethernet service supported by the VW3A58310 card in the Altivar ATV 38/58 variable speed drive:

Service	VW3A58310
I/O Scanner	-
Modbus Server	X
Modbus Client	-
Global Data	-
FDR Server	-
FDR Client	X
BootP Client	X
Time Synchronization	-
E-mail Notification	-
Web/Embedded Diagnostics	X
FactoryCast Web Server	-
SNMP	-
FTP Server	-
TFTP Server	-
Telnet Server	-

Power Logic Gateways/ Bridges

The following table lists the Ethernet services supported by the Power Logic EXG gateways:

Service	EGX200	EGX400
I/O Scanner	-	-
Modbus Server	X[1]	X[1]
Modbus Client	-	-
Global Data	-	-
FDR Server	-	-
FDR Client	-	-
BootP Client	X	X
Time Synchronization	-	-
E-mail Notification	-	-
Web/Embedded Diagnostics	X	X
FactoryCast Web Server	-	-
SNMP	X	X
FTP Server	X	X

Service	EGX200	EGX400
TFTP Server	-	-
Telnet Server	X	X
[1] Device receives and sends Modbus messages as a gateway.		

ConneXium Cabling Systems

The following table lists the Ethernet services supported by the ConneXium NES/NOS managed switches and the CEV gateways:

Service	499NES17100	499NOS17100	174CEV30020	174CEV20030	174CEV20040
I/O Scanner	-	-	-	-	-
Modbus Server	-	-	X[1]	X[1]	X[1]
Modbus Client	-	-	X[1]	X[1]	X[1]
Global Data	X[2]	X[2]	-	-	-
FDR Server	-	-	-	-	-
FDR Client	-	-	-	-	-
BootP Client	X	X	X	X	X
Time Synchronization	-	-	-	-	-
E-mail Notification	-	-	-	-	-
Web/Embedded Diagnostics	X	X	-	-	X
FactoryCast Web Server	-	-	-	-	-
SNMP	X	X	X	X	X
FTP Server	X	X	-	-	X
TFTP Server	-	-	X	X	-
Telnet Server	X	X	X[3]	X[3]	-
[1] Device receives and sends Modbus messages as a gateway					
[2] Multicast filter support for global data.					
[3] For factory diagnostic purposes only.					

3.17 System Performance Evaluation

At a Glance

Overview

This section describes how to obtain the system response times for each of the chosen communications within your plant. It also describes the checks that should be done on the devices and the network so that the overall message load on a device does not exceed its abilities and so that the overall network load does not cause communication delays.

What's in this Section?

This section contains the following topics:

Topic	Page
System Communications	320
Modbus Messaging Response Times	320
Modbus Server Response Times	321
Modbus Messaging Client Response Times	325
I/O Scanner Systems	329
Total Load on Devices	331
System Performance Solutions	332
Gateway Response Times	337

System Communications

Summary

The performance of Ethernet architecture is linked to the hardware and the application services used and to the parameters set for these services.

Hardware Considerations

- network bandwidth
- resources of module or CPU with Ethernet
- embedded processor resources (PLC, PC or other CPUs)

Application Services

- Modbus (or Uni-TE) industrial messaging handling service
- global data service, data scanning between PLC
- I/O scanning service, data scanning of distributed I/O
- others (Web access, TCP open communication)

It may be difficult to determine the correct size of an architecture because most of these parameters are linked.

Response time is determined using the graphs in Appendices A through D, showing the response times for sample systems or formula-based calculations that can be used to calculate the response time for any system.

Modbus Messaging Response Times

The Modbus messaging service involves the following components in a data transfer:

- Modbus client
- network transfer
- Modbus server

These components are the same for all Modbus messaging systems. To determine the response time of a Modbus system, the timing for each of the above items needs to be calculated. Each component can be calculated separately, and the total response time determined.

Modbus Server Response Times

Summary

Two methods can be used to determine the Modbus server response time:

- measured response times; for general times for all devices (e.g., PLCs) and as the actual value for simple devices (e.g., a VSD, an I/O block
- calculation based on system operation; for more complex devices like Quantum or Premium PLC systems

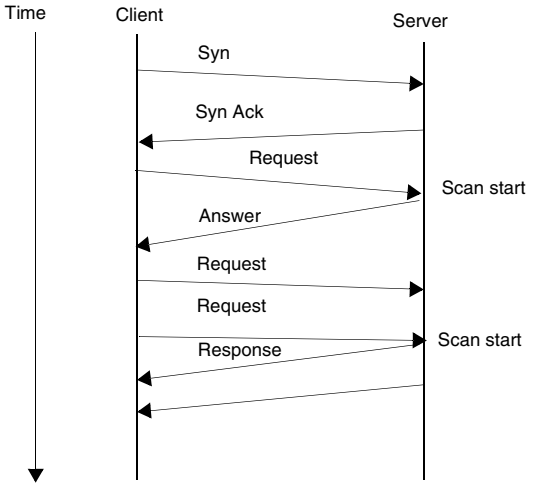
The measured response times for various Schneider Modbus server devices are described in an appendix (see *p. 401*). These response times were measured under controlled conditions and may vary from results obtained in the field. These graphs are valid only if the overall limits of device communications are not exceeded.

The Modbus server response times for the following devices are not fixed and need to be calculated:

- Premium PLC system
- Momentum PLC system
- Quantum PLC system

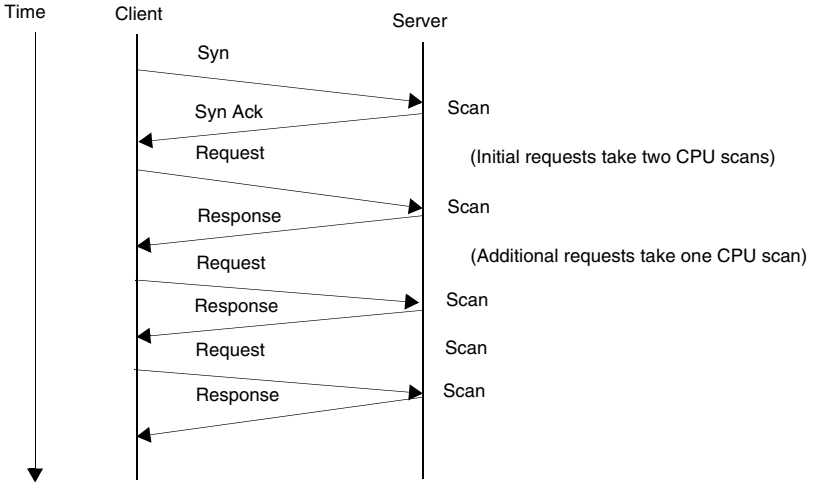
Premium PLC System

The PLC system response time for all received Modbus messaging requests is equal to one CPU scan time. All Modbus messaging requests received during the CPU scan are answered before the start of the next scan. If the total number of Modbus messaging requests received by the CPU in a single scan is greater than the limit for that type of CPU, all additional requests are answered at the end of the same scan. However, all additional requests receive the Modbus exception response *Server Busy*, instead of the actual data requested.



Momentum PLC System

The response time of a Momentum PLC system for all received Modbus messaging requests is one CPU scan time. All Modbus messaging requests received during the CPU scan are answered at the end of that current CPU scan. The PLC takes several CPU scans to answer an initial request; a TCP socket needs to be established, which takes several CPU scans.



Quantum PLC System

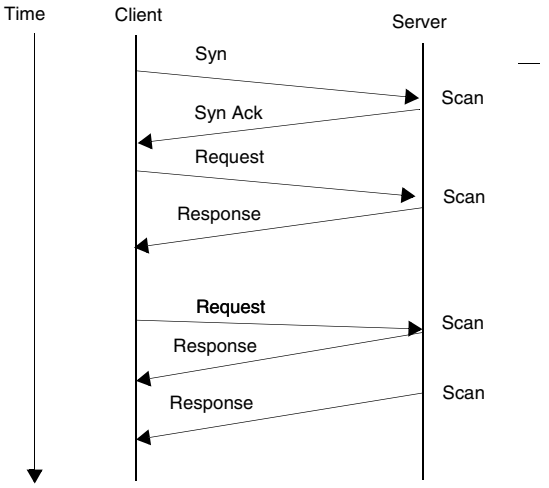
The response time of the Quantum PLC system is dependant on the number of requests being processed.

The system answers requests using three independent methods:

- direct access to the CPU memory by the NOE modules
- passing of requests to the CPU from the NOE modules
- direct access using an embedded Ethernet port on the CPU

Each method allows the PLC system to answer a specified number of requests per CPU scan. All requests arriving at the Ethernet module are placed in the queue for that module; each Ethernet port has its own queue. At the end of the CPU scan, the requests from the top of the queue are answered. Any unanswered requests remain in the queue and are answered in the order they are received. New requests placed in the queue can take one or more scans to move to the top of the queue.

If no requests are currently in the queue, the response time for a new request arriving at the PLC system is between 0 ms and one CPU scan, depending on when during the CPU scan the request arrives.



If requests are in the queue when a new request arrives, the new request is placed at the end of the queue. The new request is answered when it moves to the top of the queue. The response time can be calculated as the number of requests in the queue divided by the number of requests that can be answered per CPU scan multiplied by the CPU scan time.

Note: Each method has its own queue. Decide in which queue the new request is placed, and perform the calculations based on the number of requests in the queue.

Several milliseconds should be added to the above times to accommodate any overhead. This is much less than the CPU scan time and does not significantly affect the overall result.

Response Times for Devices

Product	Best Case	Average	Worst Case
Premium	1-2 ms	0.5 * CPU scan	1 CPU scan
Momentum	1-2 ms	0.5 * CPU scan	1 CPU scan or 2 CPU scans if initial request opens a TCP socket. Client device must be able to complete socket opening within 1 CPU scan for this to be accurate.
Quantum NOE or embedded port — no overload in number of requests, therefore no requests in the queue	1-2 ms	0.5 * CPU scan	1 CPU scan
Quantum NOE read/write register with overloaded requests	-	-	Number of requests in queue / 8 * 1 CPU scan
Quantum NOE non-read/write register with overloaded requests	-	-	Number of requests in queue / 4 * 1 CPU scan
Quantum embedded Ethernet port with overloaded requests	-	-	Number of requests in queue / 16 * 1 CPU scan

Communication Limits for Modbus Messaging

Product	Number of Requests	Number of TCP Sockets	Multiple Requests per Socket
Quantum — NOE read/write 4x register	8/ CPU scan per NOE module	64 per NOE module	yes
Quantum — NOE non 4x register	4/ CPU scan per NOE module[1]	64 per NOE module	yes
Quantum Embedded Ethernet Port	16/ CPU scan	64	yes
Premium TSXP571xx	4/ CPU scan	-	yes
Premium TSXP572xx	8/ CPU scan	-	yes
Premium TSXP573xx	12/ CPU scan	-	yes
Premium TSXP574xx	16/ CPU scan	-	yes
Premium TSXP575xx	16/ CPU scan	-	yes
Advantys	-	4	yes
ENT V1	-	4	-
ENT V2	-	4	-
Momentum	unlimited	16	no

[1] 20 / CPU scan max for all NOEs and embedded ports.

Modbus Messaging Client Response Times

Summary

The Modbus messaging client response time is part of the total Modbus messaging system response time. There are two methods for determining the Modbus client response times:

- considering the entire Modbus messaging system (client and server) as one unit
- calculating the system component times separately

In the first case, the total system response time from client request to server response is measured. The second provides more specific results for a particular system than the total time graphs used in method one.

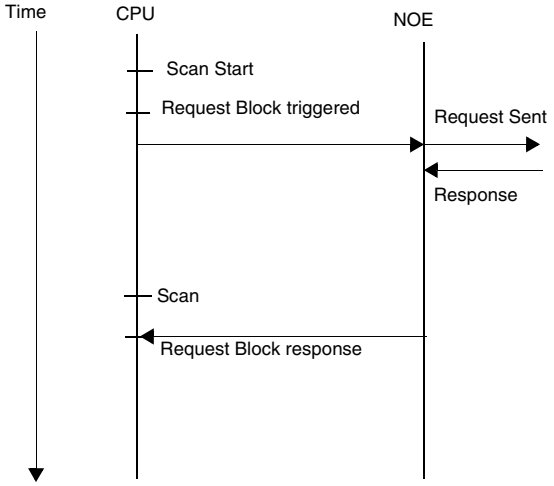
The measured response times for several of Schneider's Modbus client systems based on various server response times are described in an appendix (see *p. 405*). These response times were measured under controlled conditions and may vary from results obtained in the field. The graphs in this appendix are valid only when the overall limits of device communications are not exceeded on the client or the server.

The following devices may require the calculation of the Modbus messaging client time as it is not fixed:

- Quantum PLC system
- Premium PLC system
- Momentum PLC system
- SCADA system
- OFS server

Quantum PLC System

For a Quantum system, the Modbus messaging request is sent immediately when the function inside the user logic is triggered. When the response is received from the Modbus server, that response is processed in the user logic memory the next time the calling function is processed. This is normally during the CPU scan immediately after the PLC system has received the message.



If this is the only request being sent or there are no prior requests in the queue, the response time is:

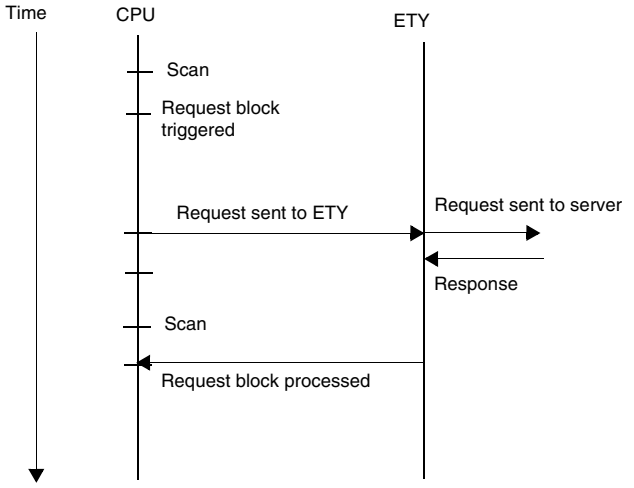
response time = *server response time* + 1 CPU scan

If the maximum number of Modbus client requests exceeds the limits of the system, the additional Modbus messaging requests are placed in a queue. Each time the requesting function is evaluated by the CPU, a check is made to see if the number of requests waiting on a response from the server is less than the maximum supported for the system. If this is true, the next request from the queue is sent to the server. The Modbus client response time is:

response time = *number of requests in the queue* x (*Modbus server response time for each request* + 1 CPU scan) + *Modbus server response time to the new request* + 1 CPU scan

Premium PLC System

For a Premium system, the Modbus messaging request is sent at the end of the CPU scan current after the function inside the user logic is triggered. When the response is received from the Modbus server, that response is processed in the user logic memory the next time the calling function is processed. This is normally during the CPU scan immediately after the PLC system has received the message.



For a Premium system the response time is:

response time = 1 CPU scan + *server response time* + 1 CPU scan

If the maximum number of Modbus client requests is exceeded, additional Modbus messaging requests are rejected and not sent; an error is generated in the user logic.

Momentum PLC System

For a Momentum system each Modbus messaging request requires that a TCP socket be opened before the request can be sent. The Modbus TCP socket is closed at the completion of each request. A Modbus client request response time is:

response time = 1 CPU scan (to send the open socket request) + *server response time to the open socket* + 1 CPU scan (to send the request) + *Modbus server response time* + 1 CPU scan (to receive the response back into the user logic)

If the maximum number of Modbus client requests is exceeded, additional Modbus messaging requests are rejected and not sent; an error is generated in the user logic.

Modbus Client Communication Limits

Product	Number of Requests	TCP Socket Usage	Multiple Requests per Socket
Quantum NOE	16	One per remote device	yes
Quantum embedded Ethernet port	64	One per remote device	yes
Premium TSXP571xx	16	One per remote device	yes
Premium TSXP572xx	32	One per remote device	yes
Premium TSXP573xx	48	One per remote device	yes
Premium TSXP574xx	64	One per remote device	yes
Premium TSXP575xx	80	One per remote device	yes
Momentum	16	One per Modbus messaging request	no

I/O Scanner Systems

Overview

The I/O scanner system operates differently in the Quantum and the Premium (see *p. 166*) PLC systems. Calculation of the system response time for either system depends on several factors and results in a complicated formula. The formula is provided for reference, but you should refer to the graphs in the appendix for most systems (see *p. 373*). These graphs provide the I/O scanner system response times from:

- field input to the PLC memory
- PLC memory to a field output
- field input to the PLC through a decision and back to a field output

Note: For the following calculations, the I/O scanner repetition rate must be set to 0 ms.
Tnet is 0.05 ms at 10 MB and 0.005 ms at 100 MB. For more accurate results, the actual network transfer time can be calculated using the number of bytes sent, the network traffic, the network speed, and the switch latency.
Tios is the number of entries in the I/O scanner table x 0.3 ms.

Response Time Formulae: Field Input to PLC Memory

For a Quantum NOE system, the response time from a field input to the information in the PLC is given by the following two formulae:

time max = *Tmod* + *Tios* + *Tnet* + 2 CPU scans

time average = *Tmod* + (*Tios* x 0.5) + *Tnet* + 1.5 CPU scans

For a Premium PLC system or a Quantum embedded Ethernet port system, the response time from a field input to the information in the PLC is given by the following two formulae:

time max = *Tmod* + *Tios* + *Tnet* + 1 CPU scan

time average = *Tmod* + (*Tios* x 0.5) + *Tnet* + 0.5 CPU scans

Response Time Formulae: Field Input to Decision to Field Output

For a Quantum PLC, the response time from a field input to a decision in a field output is:

time max = *Tmod* + *Tios* + *Tnet* + 3 CPU scans + *Tios* + *Tnet* + *Tmod*

time average = *Tmod* + (*Tios* x 0.5) + *Tnet* + 2.5 CPU scans + (*Tios* x 0.5) + *Tnet* + *Tmod*

For a Premium PLC, the response time from a field input to a decision in a field output is:

time max = *Tmod* + *Tios* + *Tnet* + 3 CPU scans + *Tios* + *Tnet* + *Tmod*

Response Time Formulae: Decision to Field Output

For a Quantum PLC, the response time from a decision to a field output is:

time max = 1 CPU scan + *Tios* + *Tnet* + *Tmod*

time average = 0.5 CPU scans + *Tios* + *Tnet* + *Tmod*

For a Premium PLC, the response time from a decision to a field output is:

time max = 2 CPU scans + *Tios* + *Tnet* + *Tmod*

time average = 1 CPU scan + *Tios* + *Tnet* + *Tmod*

Total Load on Devices

Summary Be sure that the total number of Ethernet messages being sent to and from the device does not exceed the following limits:

Processing Capacity of Ethernet Connections	**Premium Ethernet TCP/IP**			**Quantum Ethernet TCP/IP**	
	TSXETY110	TSXETY4103	TSXP575xx	140NOE771**	140CPU65150
	TSXETY210	TSXETY5103		140NWM10000(5)	140CPU65160
	TSXETY110WS	TSXWMY100(5)			140CPU67160
		TSXP571xx			
		TSXP572xx			
		TSXP573xx			
		TSXP574xx			
Message Transactions/s	60	450	500	350	350
Scanning I/O Polling Transactions/s	-	2000	2000	2000	2000
Global Data Subscription Transactions/s		800	800	800	800

System Performance Solutions

Summary

Here are several situations, presented as problems and answers, that may help when evaluating your own system's performance.

Problem 1

Problem: A single SCADA polling a Quantum PLC with an NOE module sends 15 separate requests to read blocks of Modbus 4x registers. All these requests are sent simultaneously.

How long does it take to complete all transactions when the CPU scan time is 50 ms?

Answer: The NOE module can service 8 Modbus TCP requests per PLC cycle; 15 requests take 15/8 = 2 PLC cycles. All the requests are answered in 100 ms.

Problem 2

Problem: A Premium PLC is reading data from a field device and writing the data to another field device.The input field device has a response time of 80 ms and has already processed the input to its memory. The output field device has a response time of 30 ms, and the CPU scan time is 70 ms.

What is the response time (i.e., from when the PLC reads the field input to when the new field output turns on)?

Answer: If the Premium PLC triggers a read request at the start of the CPU scan, there is a delay of one CPU scan (70 ms) before the request is sent. The field device answers after 80 ms. The response is read back into the PLC the next time the read function is called, and this can take up to one CPU scan (70 ms). The Premium triggers a write function during the same CPU scan and sends the response at the end of the scan (70 ms). The field device receives the response and sets the output (30 ms). The total time is:

70 ms + 80 ms + 70 ms + 70 ms + 30 ms = 320 ms

Problem 3

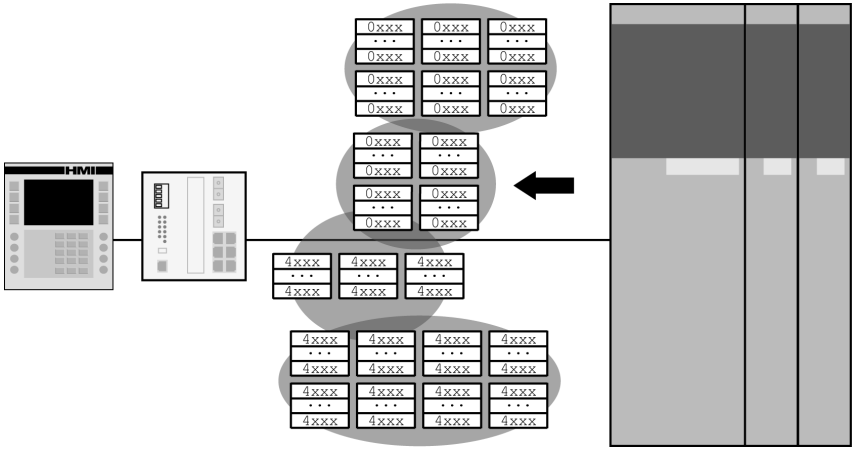
Given: A SCADA system is polling a Quantum PLC running Unity Pro software. The Quantum CPU scan time is 140 ms. The SCADA system is polling the following items every second:

- 250 registers for trending
- 750 bits for alarms
- 30 registers for a current screen being displayed
- 20 bits for a current screen being displayed
- 1 bit write to start a motor in response to a user command on the current screen

In order to calculate the number of requests, you can either look at the configuration and determine the number of requests being sent or you can estimate the number of requests. In this case, the number of requests has been provided for you. Note that not all registers are in congestive order, so the number of requests is more than the ideal amount.

- 3 requests for trending every second
- 6 requests for alarms every second
- 8 requests for registers being displayed on the screen every second
- 4 requests for bits being displayed on the screen every second

The variables are located according to the following diagram:



Problem: Determine the response time of the SCADA system in each of the following cases.

Case One: SCADA opens one socket and only sends one request at a time.

Answer: In this scenario, the SCADA only sends a new request when a response is received from the previous request. This results in the formation of a queue in the SCADA. The PLC has only one request to answer at the end of each CPU scan in which a response to the request is guaranteed at the end of each CPU scan.

In this case, there will be 21 requests in the queue. The SCADA sends the first request to the PLC; the PLC sends a response back in 140 ms, after which the SCADA sends the next request in the queue to the PLC. Therefore, the PLC takes 2.94 seconds to answer all 21 requests. SCADA system response time is 2.94 seconds.

Case Two: SCADA opens one socket, but sends multiple requests to the PLC at the same time.

Answer: In this case, the PLC has multiple requests to answer at the same time, which may exceed its ability. This results in the PLC taking multiple CPU scans to answer all requests. The SCADA sends all 21 requests to the PLC and forms two queues in the PLC, one for 0x and one for 4x. From the information above, you can see that the PLC has 11 requests in the 4x register and 10 requests in the 0x queue. The NOE can process 8 4x requests and 4 other requests per CPU scan. In this scenario, it takes 2 CPU scans (280 ms) to answer the 4x and 3 CPU scans (420 ms) for 0x requests, which is much faster than the first case.

If the user sends a write command to the PLC to start the motor, there are several possibilities:

- **Case 1a**: The SCADA may interrupt the polling and send the request right away (after the current request is finished); the motor starts two CPU scans later, one CPU scan to finish the current request and another to process the request to start the motor.
- **Case 1b**: The SCADA may place the request at the end of the queue; it takes up to 2.94 seconds before the write request is sent. The motor starts one CPU scan after this time.
- **Case 2**: The request is sent and is queued at the end of the other ox requests in the NOE module. This is processed on the third CPU scan; the delay is 3 CPU scans (420 ms).

For more information, see *p. 189*.

Problem 4

Problem: A Quantum PLC is reading data from a Premium PLC. Thee Quantum's scan time is 50 ms, and the Premium's scan time is 70 ms.

What is the response time of the system to read a block of 50 Modbus 4x registers?

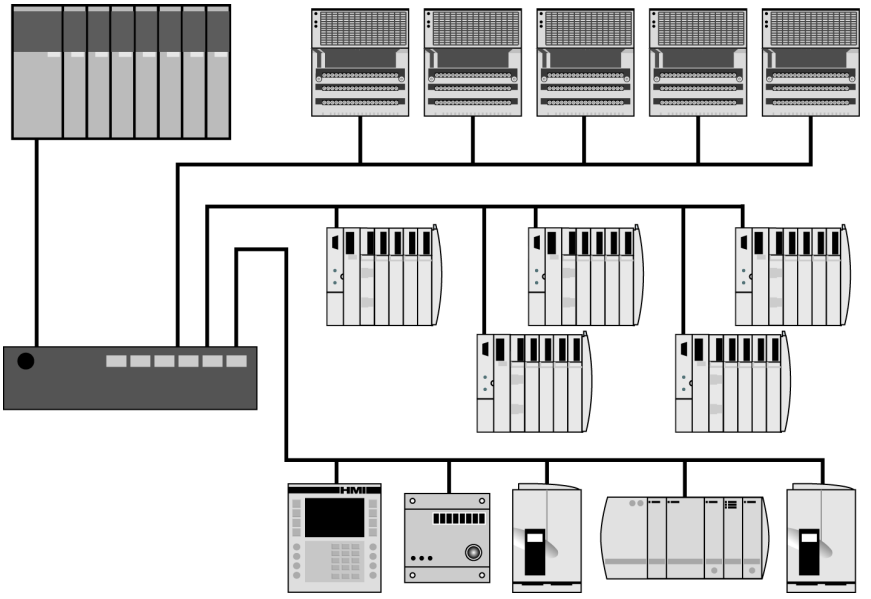
Answer: For Quantum-to-Premium communications, there are two methods: using the graphs in the appendix or calculating from the system operation. The one block of 50 Modbus registers can be read in a single Modbus request. Look for a single Modbus messaging request to a device with a response time of 70 ms. 70 ms is used because this is the scan time of the Premium PLC; a Premium PLC is able to answer requests within one CPU scan.

The Quantum PLC triggers a read request, which is immediately sent to the Premium PLC. The Premium answers this within one CPU scan time (70 ms). The Quantum receives this response and brings it into the PLC application the next time the request block is processed, causing a delay of 1 CPU scan (50 ms). The total time from when the block is triggered to when the response is available is 120 ms.

Problem 5

Problem: What is the response time for a Quantum PLC with a scan time of 50 ms to read 10 4x registers from each of 25 remote power meters that each has a response time of 100 ms?

Quantum PLC with 25 power meters having a single block of 10 registers in each power meter.



Answer: The Quantum can send only 16 messaging requests at a time from a single NOE module. There are two methods for evaluating: using a graph from the appendix or performing system evaluation.

If 25 requests are triggered, 16 are sent immediately. The meters answer after 100 ms and the responses are taken into the PLC application the next time the request block is processed. This causes a delay of 1 CPU scan (50 ms). After 150 ms the PLC has the answers to 16 requests inside the PLC application. The remaining 9 blocks are sent. The meters answer (100 ms), and the PLC reads the data in next scan (50 ms). The additional time is 150 ms. The total system response time is 300 ms.

Note: It is possible to calculate a slightly lower time if the actual timing of the other devices' response and the CPU's scan are taken into account. The response should arrive part way through a CPU scan, so you can calculate just the remaining CPU scan time before the response is processed into the application. This method is not recommended because the worst case should always be assumed. You have no control over the synchronization of the two devices.

Problem 6

Problem: A 140CPU65150 Quantum I/O scanner (with an embedded Ethernet port) on a PLC with a CPU scan time of 20 ms is polling five Momentum, Advantys and a third-party I/O devices (15 devices in all). The response time of the third-party device is 100 ms.

What are the response times for each device type to read an input, act on it in PLC code, and write a responding output to the same device?

Determine how the response time changes if the CPU scan time increases to 100 ms.

Determine how the response time changes if the CPU scan time is 10 ms but the configured repetition rate is 50 ms.

Answer: For the Momentum I/O the response time of the field device is minimal. The Momentum was used for the I/O scanner performance graphs in the appendix (see *p. 373*). The graph to evaluate the system response time is chosen on the I/O scanner processor being used and type of system (field input to field output). For 16 devices and a 20 ms CPU scan time, the system response time (from field input to field output) is 49 ms.

For Advantys devices, the response time needs to be calculated using the system formulae to take into account the field device delays.

Problem 7

Problem: A Momentum I/O device is being polled by:

- a Quantum I/O scanner reading three separate blocks of data
- a Premium PLC reading a block of data using a Modbus messaging request

If a SCADA wishes to access the Momentum is it able to read data? How can the system be changed so the SCADA is able to read data?

Answer: The Momentum I/O device can open only four TCP sockets simultaneously. The I/O scanner from the Quantum holds the TCP sockets open (the I/O scanner always hold the sockets open); the Premium PLC opens a single socket when the Modbus read request is triggered. A total of four sockets is open on the Momentum. The socket being used by the Premium could be closed after the transaction if the Momentum requests that it be closed, but the Momentum is not designed to do this. Because the maximum number of sockets open, the open-socket request from the SCADA is rejected.

To enable the SCADA system to open a socket, one of the other sockets must be closed. This cannot be done on the Premium, but the Quantum I/O scanner can close one if its sockets. It does this by disabling the line in the I/O scanner, causing the data transfer to stop but enabling the Premium to communicate. When the I/O scanner data is required, the line can be re-enabled again. The problem with this solution is that there is no coordination between the SCADA and the Quantum on which system is attempting to use the socket. This can lead to communication errors or retries if both devices attempt to read data at the same time.

Gateway Response Times

Summary

The response time for a gateway system can be calculated in one of two ways:

- Gateway with or without protocol conversion; actual calculation including response time of devices on the destination network and queues inside the gateway.
- Gateway using shared memory; For simple response time, just the time to read the internal memory can be used. For a full system response for data in a destination device through the gateway and to a device on the source network, the reading of data into the gateway (often based on a timer) must be included.

The simplest way to calculate response time is to consider a single message to read data. The following actions must occur:

- A device on the source network must send out a request to read the data; the delay is dependant on the requesting device.
- The gateway receives the request; the delay from the time the requesting device sends the request to the time the gateway receives the request is dependent on the source network. For an Ethernet network, the delay is normally 0.05 ms. For a Modbus Plus network, the delay may be up to one token rotation time, the time which it takes the token (message packet) to rotate around the ring and return to the sending device. (Refer to the Modbus Plus User's Guide for more information.)
- The gateway passes the request to the destination network; this is the gateway delay (see *p. 371*). If there is a queue, this time can be significant. Gateway delay is common if the two networks connected by the gateway have very different response times.
- The request is received by the destination device; the delay is based on the ability of the destination network to transfer the message. For Modbus Plus, this is one token rotation time. For serial networks it depends on the speed of the network.
- The request is processed by the destination device; this is dependent on the actual device.
- An answer is sent back to the gateway; the delay is based on the ability of the destination network to transfer the message. For Modbus Plus it is one token rotation time; for serial networks it depends on the speed of the network.
- The gateway passes the response back to the source network; this is the gateway delay (see *p. 371*). If there is a queue, this time can be significant. This is common if the two networks connected by the gateway have very different response times.
- The response is received by the requesting device; the delay from the time the requesting device sends the request to the time the gateway receives the request is dependent on the source network. For an Ethernet network, the delay is normally 0.05 ms. For a Modbus Plus network, the delay may be up to one token rotation time.

In steps that have a delay, the system response time is the total of all the delays.

The delay for transferring the request and the response across the network may be different. For example, a serial network takes much longer to transfer a response including 100 registers of data than it does to transfer the request itself contains no actual data.

Two items complicate the calculation of the system response time:

- a queue of messages in the gateway due to time-outs or multiple queries
- the time-out of a message on the destination network, this is applicable in a network that must hold all future messages until the current message has timed out (e.g., Modbus serial line).

To improve the system response time, limit the number of requests being sent through the gateway by limiting the number of devices connected to each gateway.

Calculation of Serial Line Transmission Time

The serial line response time is determined by the number of bits sent and the serial line speed. Refer to the Modbus protocol specification for the exact number of bits per Modbus message. For the actual network transmission time, use:

(*the number of bits in the message*/8) x (1/baud rate)

For a Modbus read request at 9600 baud, the time is about 5 ms. A response is about 100 ms for 100 registers of data.

Calculation of the Number of Supported Devices per Bridge

The system response time is determined by the number of requests sent through the bridge; the more requests sent, the slower the overall response time for all devices. To determine the number of devices on a system, first determine the total number of Modbus requests to gather all the data. The best response time the system can give is:

number of requests x (*time to transmit the request on the serial line* + *response time of the serial device* + *time to transmit the response on the serial line* + ~50 ms)

The average response time for a serial device is 200 ms, but may vary from 50 to 500 ms. The time to transmit the request/response depends on the speed of the network and the Modbus RTU/ASCII setting.

- RTU is much faster because fewer bytes are transferred.
- An average Modbus read request at 9600 baud is ~ 5 ms
- A maximum response is ~ 100 ms

The total best-case system response would therefore be:

5 ms (*request*) + 200 ms (*serial device response*) + 100 ms (*response*) + 50 ms = ~350 ms/request

For 8 Modbus devices with 2 requests each, the best-case response time to get data from the system is 16 x 350 ms = 5.6 s.

This is too long for most system users to wait for a response, so the number of devices per bridge needs to be reduced.

However, with a faster serial device response time, calculating the total best-case bridge response would use the formula:

-5 ms (*request*) + 50 ms (*serial device response*) + 20 ms (*response*) + 50 ms = ~125ms/request

For 8 Modbus devices with 2 requests each, the best-case response time would then be an acceptable 16 x 125 ms = 2.0 s.

Calculation of the Ethernet Timeout

If the time-out of a request is included, calculating the worst-case bridge response time gives the required value for the Ethernet timeout field:

Ethernet time-out = *timeout of a serial line request* x *number of serial line retries* x *number of requests sent to the bridge*

If this time-out calculation is not used, and the value in the field is too slow, the failure of one or more serial devices can cause Ethernet requests to other serial devices to time-out due to the delay caused by the incorrect value.

Troubleshooting

4

At a Glance

Introduction

This chapter describes general troubleshooting steps and provides methods for identifying problems. It also provides tables that help you identify and resolve problems.

What's in this Chapter?

This chapter contains the following sections:

Section	Topic	Page
4.1	About Troubleshooting	342
4.2	Network Troubleshooting	345
4.3	Services Troubleshooting	354
4.4	SCADA/HMI System Slow Response Time Troubleshooting	364
4.5	Bridge Troubleshooting	365
4.6	Lost Packet Troubleshooting	366

4.1 About Troubleshooting

At a Glance

Introduction

This section introduces troubleshooting for Transparent Ready networks.

What's in this Section?

This section contains the following topics:

Topic	Page
Introduction to Troubleshooting	343
General Problem Identification	344

Introduction to Troubleshooting

Overview

The troubleshooting tables in this section cover the issues you are most likely to encounter with a Transparent Ready network. Owing to the complexity of network design, it is impossible to account for every type or problem that can occur.

Here are some questions to ask yourself that cover the most common problems encountered:

- Is the device powered up?
- Are cables properly connected?
- Is the IP address correct?

To avoid redundancy, this manual explains the issues above in the network tables (see *p. 345*) and not for every service (Modbus, I/O scanner, etc.) to which they can potentially apply.

This manual is not able to anticipate defects and lockups for all devices on the market, so there are few instances in which Schneider recommends a power recycle for a network device. To achieve quick resolution, you can cycle the power on a suspect device, but you should first evaluate whether the cycle interferes with plant operations. Cycling the power may temporarily restore communications to the device, but it will not identify or correct the problem.

General Problem Identification

Before You Begin

Gather as much information as you can about the characteristics, symptoms, and behavior of an issue before you attempt to troubleshoot. Problems that initially seem to be network issues can turn out to be application issues, mismanaged end devices, or facility-related.

Ask these basic questions when you start to troubleshoot:

- Are symptoms regular or intermittent?
- How widespread is the problem? Does it affect one device, several devices, or all devices? Are the affected devices located in the same area of the site?
- Are symptoms related to one or all applications/services? What other applications/services run at the same time?
- When was the first occurrence of the problem?
- Do occurrences coincide with irregular or non-standard network activities that would not initially seem to cause problems?
- Have you changed network hardware or software components recently? Have you added end devices to the network recently?
- Could maintenance work (moving, cleaning, cable management, electrical work, etc.) affect network operations?

Keep the answers to these questions in mind when you use the troubleshooting tables.

Problem Identification

Topic	Description	Examples
Network issues	Problems with: • physical connections of devices • logical addresses • transmission of Ethernet packets to and from devices	• No light link Ethernet on device. • Cannot ping device. • Cannot contact device.
Services	Problems with one or more Transparent Ready services. A ping command can find the device and get a response, but other communications to the device may fail.	• Modbus communications failure, but web pages are OK. • I/O scanner failure, but programming is OK.
SCADA system	Specific information on performance improvement for SCADA systems.	SCADA system is slow to report field device status or execute commands.
Ethernet-to-serial bridges	Specific information on troubleshooting communications through Ethernet-to-serial bridges.	Bridge operation is slow or communications to all devices are intermittent after a single device failure.
Ethernet packet capture tool	Specific information on capturing and analyzing Ethernet packets for detailed troubleshooting.	

4.2 Network Troubleshooting

At a Glance

Introduction

This section describes network troubleshooting, mostly for layer 1 (the physical layer) and layer 2 (IP problems) of the TCP stack.

What's in this Section?

This section contains the following topics:

Topic	Page
Introduction to Network Troubleshooting	346
Connection Troubleshooting	348
Intermittent Connection Troubleshooting	350
Slow Connection Troubleshooting	351
Remote Access Troubleshooting	352

Introduction to Network Troubleshooting

Problem Types

The most common network problems on Transparent Ready systems are:

- physical
- logical
- traffic congestion

The intelligent switches and high-speed network interface cards in modern networks create complex network configurations and operations. In such an environment, problems can be hard to isolate.

Intermittent problems are the hardest to troubleshoot. It is a lot easier to tell when you've solved a constant problem than one that comes and goes.

The ability to troubleshoot a problem is often a function of the investigator's comprehension of the physical and logical network design. (The quality of on-hand documentation can also be a factor.)

Physical Connections

Physical connection problems are generally the easiest of the three common types to troubleshoot. Making sure the network cable is plugged in is only the beginning of the investigation of the network's physical connectivity. Cable testers and hardware performance indicators (often just lights on network devices) help you identify and isolate physical connection issues.

More complex physical connection problems can be related to:

cables	Did you implement the correct cable type and quality?
	Did you account for cable interference issues (noise and ground)?
	Is the implementation of straight and crossover cables appropriate?
	Are the settings and configurations appropriate for duplex (transmission speed) communications?
interference	wireless connections
	common interference

Logical Connections

To troubleshoot more complex logical connections, one must first have an understanding of physical connections and network components.

Generally, logical connection troubleshooting requires some expertise with specific software utilities and applications, although you can fix some problems with standard DOS commands that work with most off-the-shelf operating systems.

Poor network administration is often the cause of logical connection problems. If you don't restart the system before you fully test recent administration changes, end users can have problems much later, especially when they try to connect specific applications or programs after a system restart. Administration changes that are likely to cause logical connection issues include:

- critical application changes or server operating system changes (DHCP servers, DNS servers, mail servers, etc.)
- changes to logins, policies, scripting, and authentication
- security changes (firewall rules, port/services, and encryption settings)
- network hardware functionality changes (multicast filtering, default gateway routing, configuration)

Traffic Congestion

A high volume of network traffic can cause problems that are difficult to isolate and solve. Software utilities such as network sniffers and protocol analyzers help you troubleshoot congestion issues. (In most cases, you should be trained for these specific tools.) Unfortunately, the tools often indicate only general problems like broadcast errors.

In large switched networks, it is more difficult to isolate and analyze congestion without the aid of hardware probes and vendor-specific software tools. A quick understanding of the magnitude and scale of an issue can guide your attempts to find and fix the problem quickly and efficiently.

If the issue creates non-critical problems for only a few users, you might choose a troubleshooting method that does not require a complete network outage. In a case of widespread communications problems, you may need to physically segment the network to help you quickly isolate the problem.

Connection Troubleshooting

Problem	Topic	Cause and Actions
Physical check	cables (see note)	Use the proper physical cable connections from the end device to the wall, patch panel, hub, or switch. Also check for cable defects, lacerations, and causes of interference (like electrical noise). Replace questionable patch cables.
		Check device link lights, if available. Typically, lights are green when operational, amber during an error, and unlit when no physical connection is detected by the hardware. (See the hardware user guide for details)
		Check for duplex mode lights, if available, on device, for speed settings (10 mb, 100 mb, auto, etc.). Refer to Physical Layout chapter (see *p. 27*).
		Make sure that crossover cables have been used between network devices (hub-to-hub, switch-to-switch, etc.) where required. Check the device documentation for straight or crossover cable requirements.
		Cable lengths should not exceed Ethernet specifications.
		Test the backbone wire integrity with a testing device and re-terminate wiring at the patch panel if suspect after completing logical checks.
	NIC	Make sure the traditional or PCMCIA network card is properly seated in the machine. Swap the NIC card for another to test card performance.
	network hardware	Check: • hubs, switches, routers, and other network devices for power • port link lights for proper activity (typically solid or blinking green) • uplink cable connectivity for stacked devices For a suspect hub port or switch port, substitute an identical port after you have completed logical checks.

Problem	Topic	Cause and Actions
Logical check	OS	At a DOS prompt, type `ping` to check the basic level of network connectivity for replies or timeouts.
		At DOS prompt, type `ipconfig` to see if the device receives an IP address and associated IP.
		Check the operating system network configuration. For example: • Is the hardware card operational? • Are the TCP/IP protocols properly bound to NIC?
		Check the IP address configuration: • For static addressing, is the IP address and subnet mask typed correctly? • Is the default gateway address (if required) correct for source and end devices?
		If you encounter trouble while connecting to remote networks, type `trace route` at a DOS prompt to check network routing hops for failing points. If you discover a timeout at a router hop, discuss and validate the problem with the person that is responsible for that router.
		For wireless connections, check the validity of these configuration settings: • SSID • channel • type (a, b, g) • encryption key
	NIC	Check the duplex (speed) settings (autonegotiate, 10 mb, 100 mb, etc.). If possible, match the duplex settings on the end device with that of its network port.
		Make sure the network interface drivers and adapter settings have been properly installed on the end device. Update or reload the NIC software drivers from the manufacturer.
	network hardware	Enable the ports to which your hubs and switches are connected.
		Check the switch configuration for (optional) VLANs.
	applications	Check for proxy or firewall settings that can block ports or protocols between source and destination devices.
		For client/server applications, check that the server (other destination device) is properly operating on network. Check to see if other clients have the same problem to determine if the issue is with an individual client or if it is a system-wide problem.
Note: Specific tools are available to perform automatic testing of a cable. These tools test for correct cable type selection, pin connection, etc. For details on brands and models, see Physical Layout chapter (see *p. 27*).		

Intermittent Connection Troubleshooting

Problem category	Topic	Cause and Actions
Physical check	cables (see note)	• Check for loose connections, especially if there is a dongle with PCMCIA between NIC and RJ45 cable connections. • Check cables for defects. • Check the patch panel connections and grounding. • Check cable integrity with a cable testing device after completing necessary logical checks.
	NIC	With wireless connections, check the signal strength and refresh the signal or eliminate interference between an end device and a wireless access point.
Logical check	OS/applications	At DOS prompt, use the *ping* command to check the basic level of network connectivity for replies or timeouts.
		If you encounter trouble while connecting to remote networks, type trace route at the DOS prompt to check network routing hops for failing points.
		Scan the OS for virus or memory resources issues.
	network hardware	Check hubs, switches, or routers (if applicable) for network traffic congestion or possible network broadcast storms. If available, monitor the error logs on the network hardware.
	NIC	For wireless connections, use the network configuration to check the signal strength on the end device.
Note: Specific tools are available to perform automatic testing of a cable. These tools test for correct cable type selection, pin connection, etc. For details on brands and models, see Physical Layout chapter (see *p. 27*).		

Slow Connection Troubleshooting

Problem category	Topic	Cause and Actions
Physical check	cable (see note)	Check cable integrity and conformance to proper cabling requirements (category 3, 5, etc.).
		If an entire network in a large switched environment is still affected significantly after you check all logical connections, disconnect entire network segments at the central backbone location and monitor the traffic until it is normal. In this manner, you can pinpoint the specific site, building, closet, switch, port, cubicle, end device, or cable that is problematic.
	network hardware	Check the hub, switch, or router link lights for network traffic issues. Under normal circumstances, these indication lights are solid. See the device vendor documentation for interpreting blink patterns.
		Check the maximum number of repeaters (hubs) within a network segment.
		Check for loops in the Ethernet network that can be caused by: ● a ConneXium ring without a redundancy manager configured ● incorrect spanning tree setups ● a loop created by incorrect cabling among switches
Logical	OS	Scan the OS for virus or memory resource issues.
	applications	Check applications for multiple instances of overloaded system resources.
		Establish whether the problem is system-wide by examining other network devices.
	network hardware	Check hub, switch, or router (if applicable) for: ● network traffic congestion ● a possible network broadcast storm ● large bandwidth usage (large downloads, streaming audio/video, etc.) A network traffic analyzer (sniffer) can help.
Note: Specific tools are available to perform automatic testing of a cable. These tools test for correct cable type selection, pin connection, etc. For details on brands and models, see Physical Layout chapter (see *p. 27*).		

Remote Access Troubleshooting

Problem category	Topic	Cause and actions
Physical check	cables	Check for proper physical cable connections from the end device to the wall, patch panel, hub, or switch. Also check for cable defects, lacerations, and causes of interference (like electrical noise). Replace questionable patch cables with new ones (RJ-11 for dial-up). With dial-up connections, check the dial tone at the RJ-11 jack with a standard analog phone.
	NIC	Make sure the traditional or PCMCIA network card is properly seated in the machine. Test the card's performance by swapping one NIC for another.
	network hardware	Check the hub, switch, router, wireless access point, RAS server, and other network hardware for power and port link lights for proper activity (typically solid or blinking green).) Check uplink cable connectivity for stacked devices. For a suspect hub port or switch port, substitute an identical port after you have completed logical checks. (See the vendor's documentation for device-specific information.
Logical check	OS	When working remotely (at an unfamiliar hotel, conference center, customer site, etc.), verify with your network administrator that your access method is supported and allowed through the remote site's network.
		When using a VPN or dial-up connection over an existing Internet connection, verify the performance of the connection by using the Internet browser before you attempt to troubleshoot the client or server.
		When using a dial-up connection, make sure the appropriate dial-up network configuration is installed and configured.
		At the DOS prompt, use the `ping` command to check for the basic level of network connectivity for replies or timeouts. For security reasons, ICMP ping requests are sometimes blocked. Discuss this issue with the network administrator.
		At the DOS prompt, use the `ipconfig` command to see if a device receives an IP address and associated IP parameters.
		Check the operating system network configuration. For example: • Is the hardware card operational? • Are the TCP/IP protocols properly bound to NIC?
		Check the IP address configuration: • For static addressing, is the IP address and subnet mask typed correctly? • If required, is the default gateway address correct for source and end devices?

Problem category	Topic	Cause and actions
		If you encounter trouble while connecting to remote networks, type `trace route` at the DOS prompt to check network routing hops for failing points. If you discover a timeout at a router hop, discuss and validate the problem with the person who is responsible for that router.
	application	For specific VPN client software, make sure you have basic Internet access before you establish the VPN tunnel. Configure the VPN with appropriate authentication options. (See the local IT network administrator.)
		Make sure that (optional) firewall software that runs on end devices does not filter connectivity for specific applications or protocols.
	network hardware	Check the remote access server or VPN configuration (and VPN logs) for: • event information • connection attempt
		If the network uses an independent authentication server, make sure the end user accounts have been created correctly and check system logs for authentication attempts. The local system administrator can help you with this.

4.3 Services Troubleshooting

At a Glance

Introduction

This section describes common problems and actions for correcting a communications error on Transparent Ready services. Troubleshooting of this nature is simpler for some devices than for others, because diagnostic information is provided by different devices. The complexity of the troubleshooting also varies between Schneider products and third-party devices. A device's indicator lights and the information provided by its diagnostic or programming software can aid with troubleshooting.

In some cases, you can use a network packet capture tool (see *p. 368*). This tool can accurately diagnose the problem on a service and indicate a single corrective action. It can take awhile to set up the tool, so you may want to attempt an intuitive solution (swapping a suspect device or modifying a service configuration) before attempting to perform analysis with the packet capture tool.

What's in this Section?

This section contains the following topics:

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SNMP Troubleshooting	358
Telnet and FTP Troubleshooting	359
Faulty Device Replacement/BootP Troubleshooting	360
SMTP Troubleshooting	361
Time Synchronization (NTP) Troubleshooting Table	362
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Services Troubleshooting

Problem category	Topic	Cause and actions
Service failed	all services failed	You can `ping` a network device, but no other device services function (see *p. 345*).
	Modbus messaging	Modbus messaging does not function. For example: ● communications from PLC to remote devices ● communications from most SCADA systems to a PLC or device
	I/O scanner	I/O scanner service fails, as indicated by error bits that are on in the I/O scanner service.
	network management (SNMP)	A network management system is unable to read or write values to the end device. For example, a network management system can discover a device, but can not read information about the device.
	global data	The global data service fails, as indicated by health bits that are off in the global data service.
	Telnet/FTP	Telnet is unable to connect to the device, for example you can not configure a bridge device with Telnet. FTP is unable to connect or transfer files to the device, for example you can not download Web pages with an FTP client.
	faulty device replacement/BootP	A device is unable to obtain an appropriate IP address or parameters through BootP or FDR, indicated when the device continually issues BootP requests. (The LEDs indicate this error.) Otherwise, the device goes to the default IP address.
	Web	You can not access Web pages, or some Web page functions do not work correctly. For example, you can see Web pages, but live data from a device is replaced with an error message or blank space.
	NTP (time stamping)	A device is unable to obtain the time from the NTP server (or the time is not accurate).
	SMTP (e-mail)	A device is unable to send an e-mail message.

Modbus Messaging and I/O Scanner Troubleshooting

General Errors

Topic	Problem	Solution
Service response is too slow (no error generated)	This is usually caused by: ● overloaded client or server (see *p. 331*) causes slow response ● TCP socket problem or packet loss (see *p. 367*)	
Timeout error (data is not transferred)	The error response from the client identifies timeout errors, usually caused by: ● slow response from the server (see *p. 321*) ● a lost packet on the network (see *p. 367*) ● socket error (see *p. 321*)	
TCP socket error (data is not transferred)	This is an error on the TCP socket that carries the Modbus message. In this case, the TCP socket is aborted or closed before data transfer. Some devices report an error code, but most report a timeout or general error message. In the absence of a reported error, you can only discover this event with a packet capture program.	Solve this problem by correcting the TCP socket error, which can be: ● a lost packet on the network (see *p. 367*) ● a sequence or ack number problem that is caused by a problem with the TCP implementation of either end device (see *p. 367*)

Client Errors

Topic	Issue
Incorrect MAC address	An entry for the server IP/MAC address combination must be in the ARP cache of the device that sends the client request. The client device usually generates this entry, but it can be incorrect, usually when: ● a failed device is replaced with a device with a different MAC address for the same IP address ● two devices swap IP addresses and create different IP/MAC combinations for each device ● a client device saves its ARP table to flash memory, but does not refresh the table after a subsequent power-up
Client overload	An overloaded client system is not able to send requests. This is most true for systems in which the user controls the trigger request time (as in a PLC system). This issue is not common where the system (like SCADA or HMI) schedules requests. Candidates for overload are: ● the device's Modbus system ● a limit on the number of TCP sockets the device can have open (A new socket may need be opened for the transmission of a new Modbus request.) This error is normally indicated by an error message or a long delay before the request transmission.

Server Errors

Topic	Problem	Solution
Function code	All network servers do not support all function codes. A server that receives an unsupported function code will usually respond to the client with an error message. Error indication: • client reports the error • user finds the error by inspecting the network packet for either the absence of a response or a Modbus exception response Examples of newer Modbus function codes that can cause this error: • FC23 read/write registers (Quantum and Premium I/O scanners use FC23 when read and write data are listed on the same line) • Ethernet statistics or identification	Choose a supported function code to correct the error.
Request not accepted	A socket connection to the server can not be established because of: • controlled access • a firewall • the number of available server sockets is exceeded	
Register area not supported	If a request is sent to a nonexistent register area or to a range of registers that contain nonexistent registers, the server can either respond with an error code (as the Modbus specification expects) or discard the request. This error is detected through: • the Modbus error response report • examination of the documentation on the supported registers The common cause of this error is when SCADA or administration personnel try to read multiple blocks or registers in a single request from a server that implements specific registers with gaps of unsupported registers between them.	
Pipeline requests	Servers should support pipeline requests, but you should not necessarily implement pipeline requests at every opportunity. For more information, see gateway (see *p. 304*) and Modbus messaging (see *p. 179*). Pipeline requests occur when a new request is sent over a single socket before the previous request has been answered. If the server cannot process a pipeline request, it will: • respond with an error code: the error code is likely to be request not supported or server busy (especially if the server is a serial-to-Ethernet bridge) • discard the request: without a response • crash You can only identify this problem through: • knowledge of the device operation • packet inspection with an Ethernet packet capture tool A subsequent problem arises when a device sends multiple Modbus requests in a single Ethernet packet, which the Modbus specification does not permit. This can cause the same problems as above, but more likely scenarios include a request discard or a device crash.	
Incorrect response	If a Modbus request returns an incorrect response (either incorrect data or data of the wrong type or size) the client/server may be incorrectly using the Modbus transaction IDs. Transaction IDs in the Modbus TCP (not serial) specification support pipeline requests, although all devices do not implement them. This returns incorrect data, making the device non-compliant with the Modbus TCP/IP specification. Inspect the request and response with an Ethernet packet capture device to detect this problem.	

SNMP Troubleshooting

Device Discovery

Topic	Issue
A device cannot be discovered.	A known network device can not be discovered by an SNMP management system, usually because the device does not support SNMP or because a firewall blocks SNMP traffic. Check the network device with a `ping` request from a DOS prompt. If the `ping` is successful, the error is probably in the network management package. An unsuccessful `ping` indicates a likely problem with the device itself. See Network Troubleshooting (see *p. 345*).

Data Access

Topic	Issue
A device can be discovered, but cannot be accessed to read data.	• *incorrect community strings:* the read string must be correct to read data and the write string must be correct to write data • *different versions of SNMP (V1, V2, V3):* for details on versions, refer to SNMP sections of networking (see *p. 244*).

Telnet and FTP Troubleshooting

These tables describe troubleshooting for Telnet (see *p. 247*) and FTP (see *p. 256*) issues

Device Access

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Topic	Problem	Solution
Cannot access device.	A firewall is a common access restriction.	An error message on the client side can sometimes detect this problem, but in a more ideal situation: ● The user is already aware of the firewall. ● The user examines the packets with an Ethernet packet capture tool to verify proper transmission of the socket open request, but a socket is not established because no response is received.

Incorrect Login or Restricted Access

Topic	Issue
Cannot log in to the device or cannot perform the desired action.	An incorrect username or password is usually the cause of this problem. The user interface can detect this problem and display an error message. In the absence of a user interface, the problem can be hard to distinguish from the previous error (above).
Cannot perform the desired function.	This problem is common when the current username does not provide access to the desired action (for example, an attempt to write a file is made with a read-only login). The user interface can detect this problem and display an error message. In the absence of a user interface, the problem can be hard to distinguish from the previous error (above).

Faulty Device Replacement/BootP Troubleshooting

These tables describe troubleshooting for faulty device replacement (see *p. 204*) and BootP (see *p. 134*).

Address Assignment

Topic	Problem	Solution
No response from the server to a request for an IP address	• The server does not list the device by either rolename or MAC address. This usually happens when you add a replacement device (with a new MAC address) without updating the server table. • A firewall or router prevents the client from reaching the server. Set up the server as a DHCP relay agent to correct the problem. When the client does not obtain an IP address, it either reports an error code or goes to the default IP address (or both).	If you are not familiar with the network, use an Ethernet packet capture tool to detect the problem.
Slow response from the server causing a timeout on the client	A server can respond slowly when: • overloaded, for example, many devices powered up at the same time • client and server are powered on at the same time (generally, client devices boot up faster and can send a request to the server before the server is operational) When there is a slow server response, the client does not get an IP address. It either reports an error code or goes to the default IP address (or both).	You can distinguish slow server responses from the errors above only with a packet capture tool. Use an Ethernet packet capture tool to detect the problem
Server sends negative response, preventing the device from obtaining an IP address	Multiple DHCP/BootP servers connected to the same network can create multiple responses to the same request. One server response can offer the correct address while another server response reports that no address is available. The negative response can cause the client to go to an error state or assume a fallback address.	You can distinguish this problem from the errors above only with a packet capture tool. Use an Ethernet packet capture tool. This is seen as the client not obtaining an IP address. (The client device may report an error code or go to the default IP address.)

Configuration File

Topic	Problem
IP address obtained but no configuration file for an FDR system	A firewall in front of the FDR server may allow the DHCP request (for an IP address) but block the FTP/TFPT request for the configuration file. When a PC used as an FDR server, the file server can be on a different (unreachable) machine.

SMTP Troubleshooting

These tables describe troubleshooting for SMTP issues (see *p. 358*).

Cannot Connect to Server

Topic	Problem	Solution
Firewall		Check that firewall allows SMTP traffic.
Password i	Password incorrect	Check that the server uses the same password scheme as the client. Check that the passwords are correct.

Cannot Send Messages

Topic	Issue
Server failure	Check server connection error counter.

Messages Slow to Arrive

Issue	Solution
Server delays	Send e-mail from PC client to confirm that it is a server delay and not a client delay. If server delay is confirmed, consult the IT staff.

Time Synchronization (NTP) Troubleshooting Table

These tables describe troubleshooting for time synchronization (NTP) (see *p. 208*).

Cannot Obtain Time From Server

Topic	Issue
Time exchange format is incorrect	The server might implement SNTP broadcasts. Schneider devices support only NTP/SNTP request responses (not broadcasts). You can find this problem through the examination of device configurations.
Cannot obtain time from the server	The server might be behind a firewall.

Time Obtained Is Not Accurate

Topic	Problem	Solution
Server time is inaccurate or unstable	The server time is not accurate, especially if the network uses a PC (instead of a dedicated server) as an NTP server. Windows PCs are the most likely to create this problem, whereas a Linux PC or dedicated time server can solve it.	
Network delays cause time inaccuracies	Non-uniform network loads can cause large delays in either the request or response message because NTP algorithms that calculate accurate times assume uniform network delays. You can find this problem through the examination of network loads or by using an Ethernet packet capture tool to capture request and response packets. Some devices also list delays on a diagnostics page.	To solve this problem, move the server closer to the network client device through: • the elimination of routers and switches between the server and client • the implementation of a separate network (possibly a VLAN) for the NTP system

Web Troubleshooting Table

Cannot Access Static Pages

Topic	Problem	Solution
Firewalls		Make sure you have the appropriate security access for all devices that you try to reach. Also, the firewall should be configured to allow access to your HTTP request.
Proxy server	A proxy server can allow access to only the appropriate Web pages through filtering. Make sure the proxy server does not filter out the Web page you want to reach.	

Cannot Access Dynamic Data

Topic	Issue
Java version	If you can see the Web pages but not the dynamic data (like Ethernet statistics), the Java applet may not be compatible with your JVM. A gray Java box or an error in the status bar at the bottom of the Web browser window indicate this problem.
firewall	A firewall can also block the particular application protocol (like Modbus TCP and Uni-TE (502)) so you can not see live data. For example, a Web page that can not display real-time data indicates that protocol 502 is blocked. If this is the case, you see either: ● question marks in the data fields, or ● an error indicating that the Modbus device can not be reached
browser security setting	You can not download Java applets if you chose high security settings in your Internet options. In this case, a security error in the status bar at the bottom of the Web browser window indicates this problem.
access control on Modbus	Check the Schneider device to make sure your IP is listed as a designated IP for communications with the device. If this is the case, you see either: ● question marks in the data fields, or ● an error indicating that the Modbus device can not be reached

4.4 SCADA/HMI System Slow Response Time Troubleshooting

Slow Response Time (SCADA/HMI) Troubleshooting

Problem Category	Topic	Suggestions
Determine the cause of the delay	Determine if the delay is on write traffic or read traffic	Send a device operation command and measure the interval between the command transmission and the device reaction. Determine: ● Is the delay in data writing or response reading? ● Is there a difference between digital and analog data reading and writing? **Note:** Determine the device reaction from physical observation of the actual device, not from the status display on the SCADA/HMI system.
	Determine if the delay is SCADA-based or server-based	With a separate PC tool, send a single request to the server and measure the response time. Separate read and write requests should be sent for each data type the SCADA system reads. ● A fast response from the PC and a slow response from the SCADA indicates a problem in SCADA communications. SCADA responses might be slowed down by either the SCADA system or by a SCADA request queue inside the server. (Other requests, such as PC requests are not held up in this queue). ● A slow response from the PC indicates an overloaded server, so you reduce the load on the server (see *p. 281*).
Slow response caused by SCADA	SCADA is slow but PC test tool is fast (check server response time for SCADA requests)	Examine the response time of a SCADA request on the server with an Ethernet packet capture tool. To do this, check one of each request type (read, write, digital, analog) that the SCADA uses. When doing this measurement, you may see that after you send the request to be measured the server will send back some responses to earlier requests. It is important to wait for the response to the specific request you sent before calculating the response time. To identify a specific request/response pair, either the Modbus transaction ID or another unique feature of the request must be used (for example, the number of requested registers). If the observed response time is slow, then a queue of SCADA requests in the server can cause a long delay. To improve the response: ● Reduce the number of requests sent to the server. (see *p. 281*) ● Start an additional queue for data access and send requests on that path. This works because the PC is able to get a fast response, showing that the server is not overloaded. To do this, force the SCADA to open extra TCP sockets and split the requests between the sockets.
	SCADA is slow but PC is fast and there is no delay on SCADA requests in the server device	A queue in the SCADA system itself causes this delay. This can happen when the SCADA sends only a single request at a time to the server. This usually happens in systems for which only a single TCP socket to the server exists. The SCADA section (see *p. 274*) gives information for opening more sockets or sending more requests down a single socket elsewhere in this document.

4.5 Bridge Troubleshooting

Bridge Troubleshooting

Problem Category	Topic	Suggestions
Slow response or communication failure	slow response	There are too many devices on the serial line side of the bridge.
	socket rejected	Most bridges can only implement a limited number of Ethernet sockets. This number is usually less than the number of devices connected to the serial line side. Therefore, if one socket is used per serial device, the number of available bridge sockets will be inadequate. To solve this, reduce the number of devices on the serial line or select the Modbus client device that can send requests to multiple serial devices over a single socket. For an I/O scanner system that scans devices over a bridge, either implement the enable/disable feature or change to the Modbus client communication blocks instead of the I/O scanner. The client may report this error. Otherwise, you must either ascertain the number of sockets in use (through analysis of the communications) or use an Ethernet packet capture tool to see the socket rejection.
Intermittent communications failures	additional devices fail after one fails	Timeouts on the Ethernet side are not long enough. (They are less than the total timeouts on the serial side.) Refer to gateway section (see *p. 304*) for more information.
	intermittent errors	Timeouts on the Ethernet side are too close to the time required for gathering serial line data. Refer to gateway section (see *p. 304*) for more information.

4.6 Lost Packet Troubleshooting

At a Glance

Introduction

This section describes troubleshooting for lost data packets.

What's in this Section?

This section contains the following topics:

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Lost Packet Troubleshooting	367
Using a Packet Capture Tool	368
Packet Capture Troubleshooting	369

Lost Packet Troubleshooting

Problem Category	Topic	Cause and Actions
General	effect of a lost packet	A lost packet causes an error on a TCP socket. Normally, the socket recovers from the error, avoiding notice in the application layer (for example, Modbus or I/O scanner). However, an error occurs in the application layer when the time to recover is longer than the application layer timeout.
	detecting lost packets	There are two ways to detect lost packets: • *sent/received packet counter:* Use this method when you can verify that one packet is sent for each one received (for example, a system that only has Modbus client/server traffic). Counters are also suited for detecting large numbers of lost packets. • *Ethernet packet capture tool:* Use this method to see the TCP sequence and acknowledgment numbers to identify lost packets. Packet captures should use the timestamp feature to correlate the time of packet loss with the alarm time on a SCADA system or time of a problem in the plant.
Responding to packet loss	packet lost in a switch or network device	You see this error when a packet appears on one side of a switch but not the other. This requires the simultaneous implementation of two packet capture tools. To resolve this, check the switch load. Network devices discard some packets when the switch is overloaded. Electrical noise can also cause packet corruption, forcing a packet to be discarded.
	packet loss causes an application error	If a packet loss causes an application error: • extend the application timeout to allow for the recovery of TCP layer • modify the devices for faster TCP layer recovery (requires a firmware change) • reduce the number of packets lost Sample ways to reduce the number of lost packets: • reduce network traffic • eliminate half-duplex links • reduce electrical noise These changes only reduce packet loss. They do not eliminate the problem.

Using a Packet Capture Tool

Overview

In an ideal system, all devices would detect and report the exact cause of network errors, but this is not always possible. A device can be unable to detect or report an error.

If the device indicates only a general error (instead of a specific error), you can use an Ethernet packet capture tool to monitor the Ethernet packets and determine the specific error and its cause. This allows you to determine the actual error and layer (IP/TCP or application) on which the error occurs so you can take corrective action. We do not recommend packet capture tools for general plant maintenance, but they are well-suited for diagnosing intermittent problems or problems that occur during device installation.

These tools capture network packets and display them on the screen. The tools also save the packets in a file that you can analyze later.

Tool Types

Ethernet packet capture tool types:

- *physical layer:* These expensive tools capture physical signals on the wire and logical data on the upper layer.
- *hand-held:* These tools analyze only layers 2, 3, and 4. They are not quite as expensive as physical layer tools, and are rugged enough for field use.
- *PC-based:* These tools use a PC's Ethernet card to capture network data for analysis in a software program. Owing to wide fluctuations in price (from freeware to more than USD$20,000), the degree of automatic analysis and customer support services for these tools significantly vary. These tools analyze only layers 2, 3, and 4.

Tool Capabilities

Ethernet packet capture tools can detect or determine:

- overall network traffic load: Which devices contribute to congestion? What is the nature of the traffic? (VoIP? Windows broadcast? I/O scanner traffic?)
- broadcast traffic and its causes
- a list of devices to which a specific device transmits and the communication protocol it uses
- details of communications between devices: protocols, function codes, the addresses and values of transferred/requested data
- a device's application layer response time
- packet loss or multiple TCP retries
- communications to and from a device that suffers from TCP socket errors (rejected connections, lost packets, etc.)

All Ethernet packet capture tools can analyze all of these items, but better tools do analysis automatically and report errors on the alarm screen.

Packet Capture Troubleshooting

Problem Category	Topic	Suggestions
Packets from the required device are not seen	only packets to or from the host PC are captured by the tool	The package does not operate in *promiscuous mode*. Enable this mode to allow the computer to capture all data seen on the Ethernet cable connected to the computer. For most tools, you can set this as a general option within the tool for all captures or set it when the capture starts. You need a special Ethernet card driver to enable this setting. Most tools include Ethernet card drivers, but all cards don't always function on all systems.
	packets from the device being analyzed are not captured, but broadcast packets are	When a packet arrives at a switch, the switch sends the packet out on only the port that is ultimately connected to the destination device. As a result, a packet capture tool connected to a spare port on the switch will not see the packet. To allow the packet capture tool to see the packet, do one of the following: • Replace the switch with a hub: In this case you'll see traffic to and from all devices connected to the hub. • Insert a hub between the device in question and the switch: The packet capture tool is then connected to the hub, in which case you'll see only packets to and from the device in question. • Enable port mirroring: This configures the switch to forward a copy of all packets sent or received on a port to a different port to which the packet capture tool is connected. (Port mirroring is not supported by all switches.) • Configure the switch to operate as a hub: Some switches support this feature as a disable learning option. In this case, the switch no longer determines the data destination and sends all data to all ports. **Note:** These solutions result in data transmission to Ethernet ports that do not normally receive data when the network is not under analysis. This can result in increased traffic on the network (among other undesirable results).
Finding the error packets within a capture	capturing data for intermittent errors causes files of excessive size	For errors that occur every few minutes or hours, a capture setup may have to run for several hours. This creates many thousands of packets in the file that has to be analyzed during error investigation. Because such a large file consumes hundreds of MB of disk space, it is impractical to run an analyzer for 24-hour periods. Therefore, an error may not necessarily occur when the analyzer happens to be running. To avoid this, the packet capture tool can be set to limit the duration of data collection or the number of packets in the capture file. At the predefined limit, the file closes and the tool starts a new file. After the configured number of files have been created, the tool either stops recording or begins to overwrite the files in order in which they were created. Each such file is time-stamped when the tool closes it. Using a SCADA system or other plant system to record error times (for example, plant stoppage or and unavailable device), you can open the correct file to find packets that were exchanged at the time of the error. The tool marks each packet with the exact time so you can find specific packets at the time of the error. Note that packets showing the problem are usually seen just before SCADA reports the error because of timeout and reporting delays.
	filter the captured data (to just the required packets)	Use data filtering to find the packets you want to investigate. Filter packets with one of two methods: • *during the capture stage:* Filtering during capture can discard packets that are needed for analysis later. If that happens, you have to do another capture. • *in the stored data:* This is the suggested method. Filter according to address (IP or MAC) and protocol (destination socket number). Then filter the visible data to a single TCP socket based on source socket number.

Appendices

What's in this Appendix?

The appendix contains the following chapters:

Chapter	Chapter Name	Page
A	I/O Scanning Response Times	373
B	Modbus Server Throughput Capacity	401
C	Modbus Client Response Times	405
D	Gateway Response Time and Timeout Measurements	445
E	Standards and Other Considerations for Industrial Ethernet Networks	479
F	Earthing (Grounding) Procedures	499

I/O Scanning Response Times

A

At a Glance

Overview

This appendix illustrates some I/O scanner response times for Premium and Quantum systems that use industrial Ethernet.

What's in this Chapter?

This chapter contains the following sections:

Section	Topic	Page
A.1	Premium PLC I/O Scanner Response Times	374
A.2	Quantum PLC I/O Scanner Response Times	387

A.1 Premium PLC I/O Scanner Response Times

At a Glance

Overview

The system response time curves illustrated in this section are based on measurements made on Premium PLCs that are scanning Momentum 170 ENT 110 00 devices. Momentum was used because it provides the shortest response times for Ethernet applications (approximately 5 to 8 ms). Three different types of response time scenarios are presented.

What's in this Section?

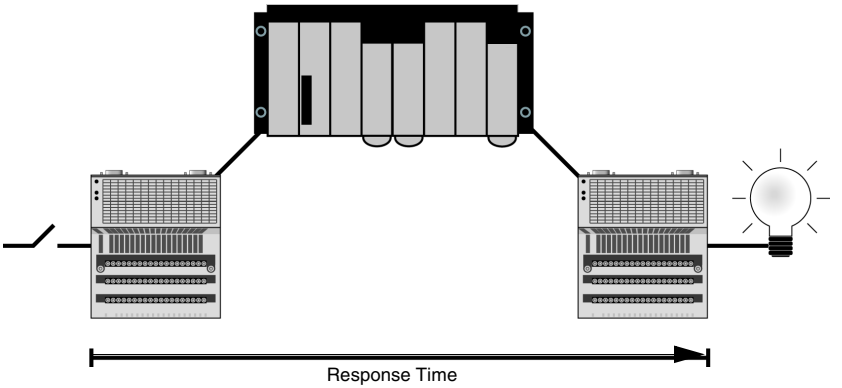
This section contains the following topics:

Topic	Page
Premium I/O Scanner Response Times: Remote Input to Remote Output	375
Premium I/O Scanner Response Times: Remote Input to a Local Output	379
Premium I/O Scanner Response Times: PLC Memory to Remote Output	383

Premium I/O Scanner Response Times: Remote Input to Remote Output

Measurement Setup

The set of curves below illustrates Premium PLC response times when a signal is sent from a remote input module through the PLC to a remote output module:



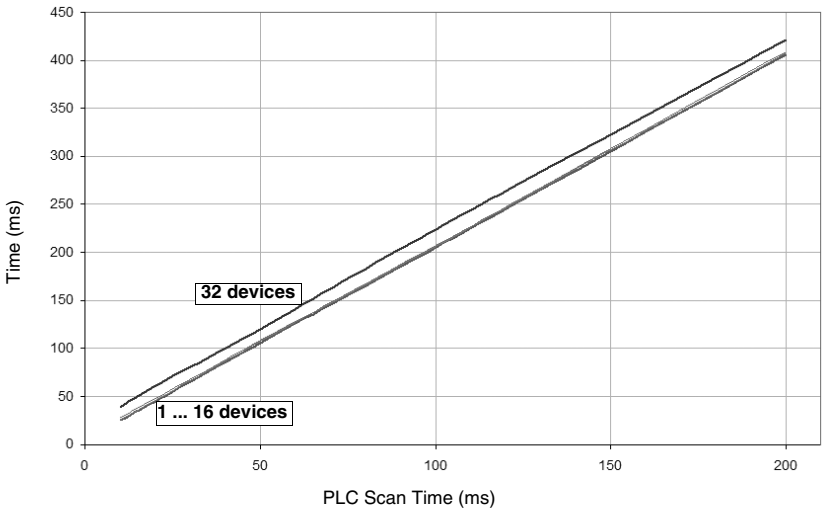
The signal is:

- triggered by a Momentum input module with a response time of ~2 ms
- scanned into the Premium PLC at a repetition rate of 0 ms (see *p. 174*)
- copied to another internal variable within the PLC
- written to a Momentum output module with a response time of ~2 ms

Results are plotted for 1, 8, 16 and 32 devices.

TSXP575634M CPU with Embedded Ethernet Port

The TSXP575634M CPU used for the following measurements is at version 2.0, with its embedded Ethernet port at version 2.0.



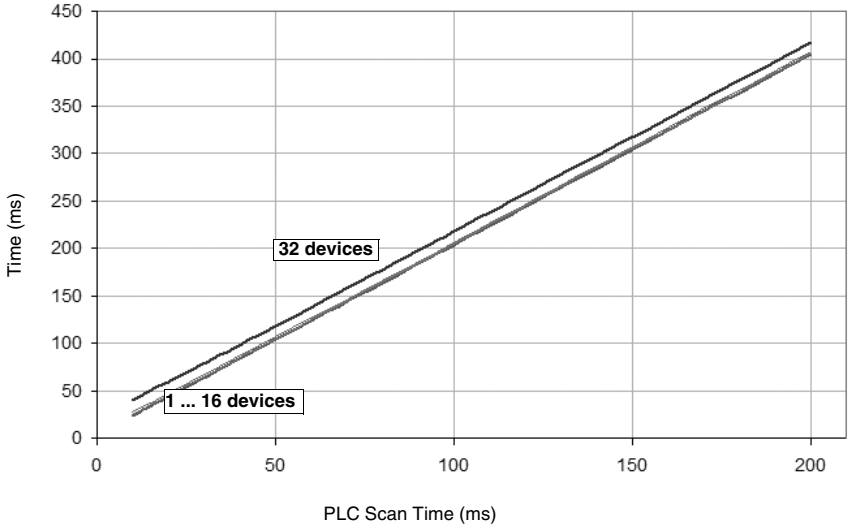
The bottom curve shows that the response times for 1 to 8 devices are within 1 ms of each other. The response times for 16 devices increase by 2 to 3 ms. For 32 devices, response times are approximately 11 to 14 ms longer.

The table below shows the data points used to generate the graph represented above.

Number of Devices to Scan	**Time from Scanned Device Input to Scanned Device Output (ms)**				
TSXP575634M (v2.0) + Embedded Ethernet Port (v2.0)	**10 ms Scan**	**20 ms Scan**	**50 ms Scan**	**100 ms Scan**	**200 ms Scan**
1 device	25	45	106	205	406
8 devices	26	46	107	206	407
16 devices	28	48	108	207	409
32 devices	39	61	120	224	421

TSXP575634M CPU with a TSXETY5103 Module

The TSXP575634M CPU used for the following measurements is at version 2.0, and the TSXETY5103 Ethernet communications module is at version 3.1.



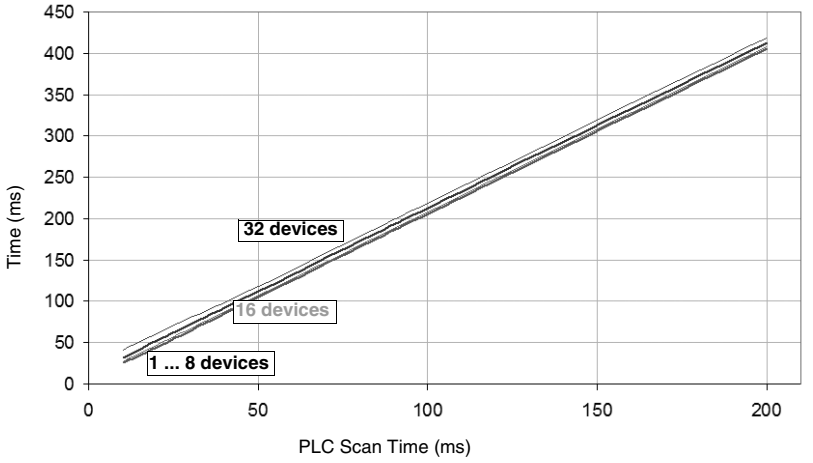
The bottom curve shows that the response times for 1 to 8 devices are within 1 ms of each other. The response times for 16 devices increase by 2 to 3 ms. For 32 devices, response times are approximately 12 to 16 ms longer.

The table below shows the data points used to generate the graph represented above.

Number of Devices to Scan	Time from Scanned Device Input to Scanned Device Output (ms)				
TSXP575634 (v2.0) + ETY 5103 (v3.1)	**10 ms Scan**	**20 ms Scan**	**50 ms Scan**	**100 ms Scan**	**200 ms Scan**
1 device	24	44	104	204	405
8 devices	25	45	105	205	406
16 devices	28	47	107	206	408
32 devices	40	60	118	218	417

TSXP57304M CPU with a TSXETY5103 Module

The TSXP57304M CPU used for the following measurements is at version 2.0, and the TSXETY5103 Ethernet communications module is at version 3.1.



The bottom curve shows that the response times for 1 to 8 devices are within 2 ms of each other. The response times for 16 devices increase by 3 to 4 ms. For 32 devices, response times are approximately 10 to 16 ms longer.

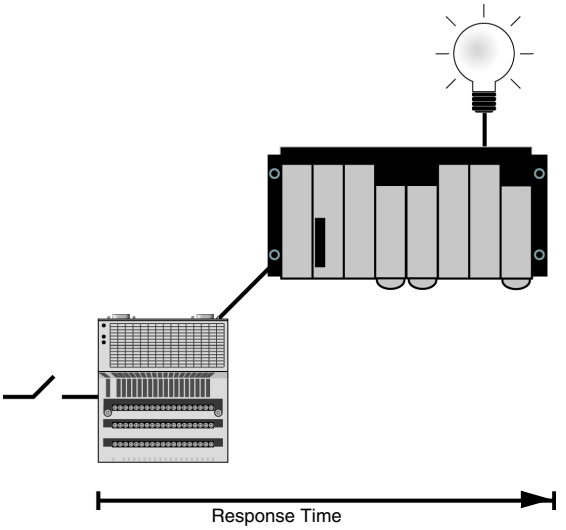
The table below shows the data points used to generate the graph represented above.

Number of Devices to Scan	**Time from Scanned Device Input to Scanned Device Output (ms)**				
TSXP57304M (v2.0) + ETY 5103 (v3.1)	**10 ms Scan**	**20 ms Scan**	**50 ms Scan**	**100 ms Scan**	**200 ms Scan**
1 device	25	44	105	206	406
8 devices	27	47	107	208	408
16 devices	31	52	112	213	413
32 devices	41	601	118	219	419

Premium I/O Scanner Response Times: Remote Input to a Local Output

Measurement Setup

The set of curves below illustrates Quantum PLC response times when a signal is sent from a remote input module to a Premium output module in the PLC:



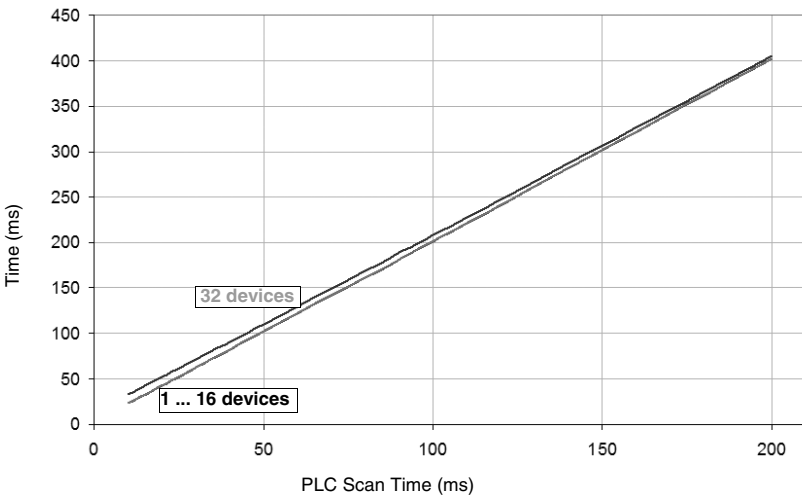
The signal is:

- triggered by a Momentum input module with a response time of ~2 ms
- scanned into the Premium PLC at a repetition rate of 0 ms (see *p. 174*)
- copied to another internal variable within the PLC
- written to a local Premium output module

Results are plotted for 1, 8, 16 and 32 devices.

TSXP575634M CPU with Embedded Ethernet Port

The TSXP575634M CPU used for the following measurements is at version 2.0, with its embedded Ethernet port at version 2.0.



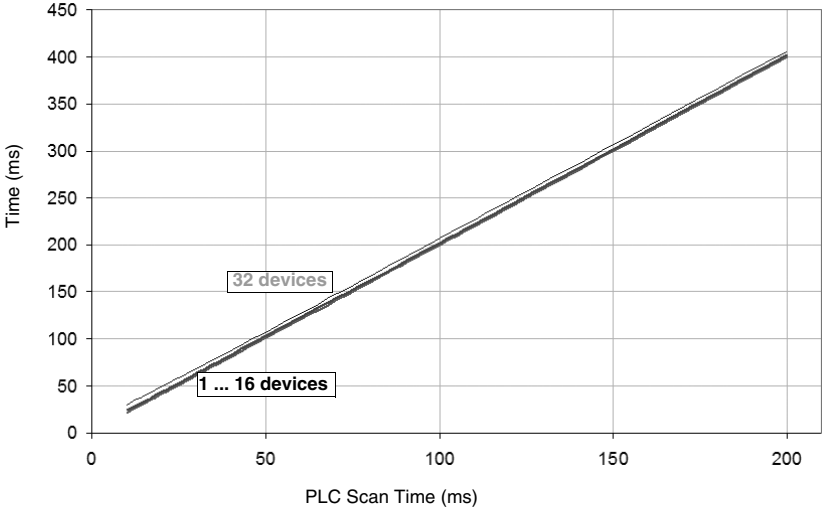
The bottom curve shows that the response times for 1 to 16 devices are within 1 ms of each other. The response times for 32 devices are 9 to 10 ms longer initially; as scan time increases, the difference in response times becomes smaller.

The table below shows the data used to generate the graph represented above.

Number of Devices to Scan	**Time from Scanned Device Input to Local Output (ms)**				
TSXP575634M (v2.0) + Embedded Ethernet Port (v2.0)	**10 ms Scan**	**20 ms Scan**	**50 ms Scan**	**100 ms Scan**	**200 ms Scan**
1 device	23	42	102	201	402
8 devices	23	42	102	201	402
16 devices	24	43	103	202	403
32 devices	33	52	110	208	405

TSXP575634M CPU with a TSXETY5103 Module

The TSXP575634M CPU used for the following measurements is at version 2.0, and the TSXETY5103 Ethernet communications module is at version 3.1.



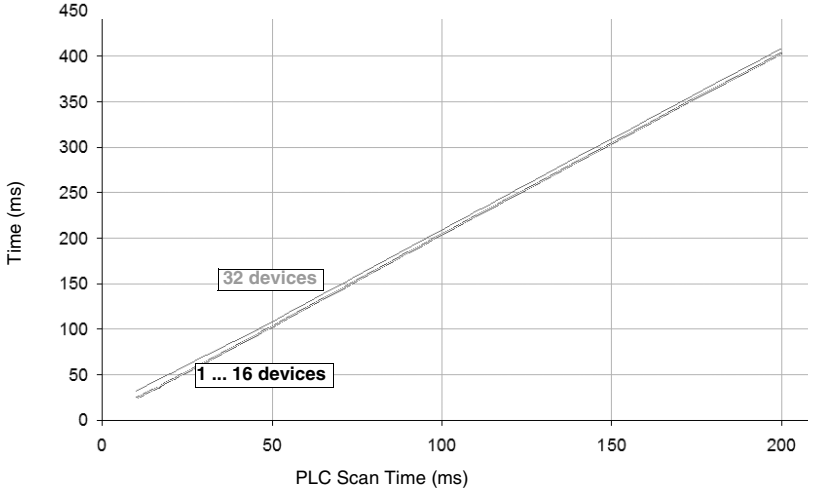
The bottom curve shows that the response times for 1 to 16 devices are within 3 ms of each other. The response times for 32 devices are 6 to 9 ms longer initially; as scan time increases, the difference in response times becomes smaller.

The table below shows the data points used to generate the graph represented above.

Number of Devices to Scan	Time from Scanned Device Input to Local Output (ms)				
TSXP575634M (v2.0) + ETY5103 (v3.1)	**10 ms Scan**	**20 ms Scan**	**50 ms Scan**	**100 ms Scan**	**200 ms Scan**
1 device	21	41	101	200	400
8 devices	22	42	102	201	401
16 devices	24	43	103	202	402
32 devices	30	49	107	207	406

TSXP57304M CPU with a TSXETY5103 Module

The TSXP57304M CPU used for the following measurements is at version 2.0, and the TSXETY5103 Ethernet communications module is at version 3.1.



The bottom curve shows that the response times for 1 to 16 devices are identical or within 1 ms of each other. The response times for 32 devices are 6 ms longer initially; as scan time increases, the difference in response times decreases slowly.

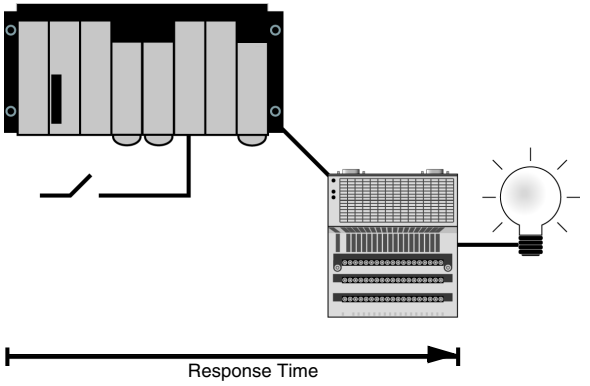
The table below shows the data used to generate the graph represented above.

Number of Devices to Scan	Time from Scanned Device Input to Local Output (ms)				
TSXP57304M (v2.0) + ETY5103 (v3.1)	**10 ms Scan**	**20 ms Scan**	**50 ms Scan**	**100 ms Scan**	**200 ms Scan**
1 device	24	43	103	204	404
8 devices	24	43	103	204	404
16 devices	24	43	103	204	404
32 devices	32	51	108	209	409

Premium I/O Scanner Response Times: PLC Memory to Remote Output

Measurement Setup

The set of curves below illustrates Quantum PLC response times when a signal is sent from the PLC to a remote output module:

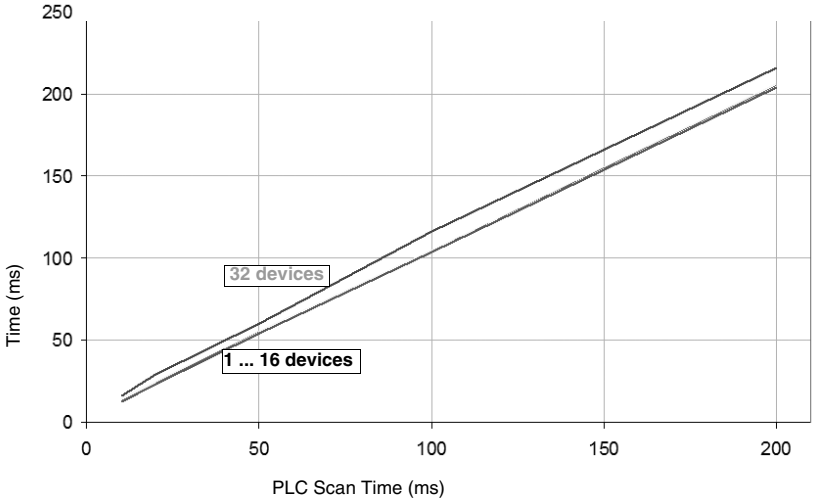


The signal is written to a Momentum output module with a response time of ~2 ms.

Results are plotted for 1, 8, 16 and 32 devices.

TSXP575634M CPU with Embedded Ethernet Port

The TSXP575634M CPU used for the following measurements is at version 2.0, with its embedded Ethernet port at version 2.0.



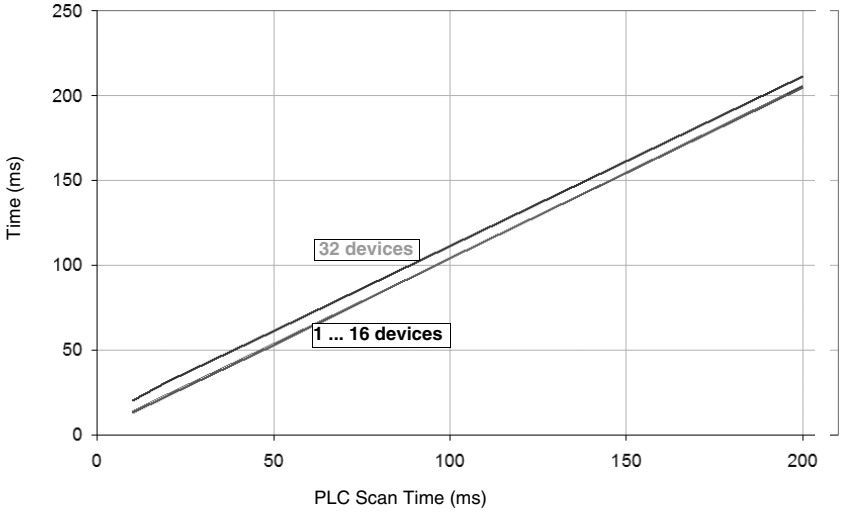
The bottom curve shows that the response times for 1 to 16 devices are within 1 to 2 ms of each other. The response times for 32 devices are 2 to 4 ms longer initially; as scan time increases, the difference in response times becomes larger.

The table below shows the data points used to generate the graph represented above.

Number of Devices to Scan	**Time from PLC Memory to Scanned Device Output (ms)**				
TSXP575634M (v2.0) + Embedded Ethernet Port (v2.0)	**10 ms Scan**	**20 ms Scan**	**50 ms Scan**	**100 ms Scan**	**200 ms Scan**
1 device	12	23	54	104	204
8 devices	13	23	55	105	205
16 devices	14	25	55	105	206
32 devices6	16	29	60	116	216

TSXP575634M CPU with a TSXETY5103 Module

The TSXP575634M CPU used for the following measurements is at version 2.0, and the TSXETY5103 Ethernet communications module is at version 3.1.



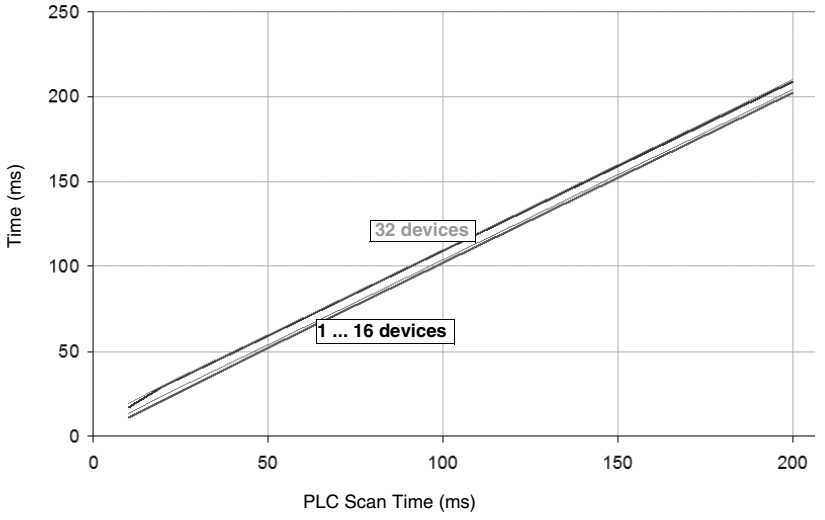
The bottom curve shows that the response times for 1 to 16 devices are within 1 to 4 ms of each other. The response times for 32 devices are 6 to 9 ms longer.

The table below shows the data points used to generate the graph represented above.

Number of Devices to Scan	**Time from PLC Memory to Scanned Device Output (ms)**				
TSXP575634M (v2.0) + ETY5103 (v3.1)	**10 ms Scan**	**20 ms Scan**	**50 ms Scan**	**100 ms Scan**	**200 ms Scan**
1 device	13	23	53	104	205
8 devices	13	23	53	104	205
16 devices	14	24	54	104	206
32 devices6	20	31	61	111	211

TSXP57304M CPU with a TSXETY5103 Module

The TSXP57304M CPU used for the following measurements is at version 2.0, and the TSXETY5103 Ethernet communications module is at version 3.1.



The bottom curve shows that the response times for 1 to 16 devices are identical. The response times for 32 devices are 8 ms longer initially; as scan time increases, the difference in response times becomes smaller.

The table below shows the data points used to generate the graph represented above.

Number of Devices to Scan	Time from PLC Memory to Scanned Device Output (ms)				
TSXP57304M (v2.0) + ETY5103 (v3.1)	**10 ms Scan**	**20 ms Scan**	**50 ms Scan**	**100 ms Scan**	**200 ms Scan**
1 device	11	21	52	102	202
8 devices	13	24	54	104	204
16 devices	17	29	59	109	209
32 devices6	19	30	60	110	210

A.2 Quantum PLC I/O Scanner Response Times

At a Glance

Overview

The system response time curves illustrated in this section are based on measurements made on Quantum PLCs that are scanning Momentum 170 ENT 110 00 devices. Momentum was used because it provides the shortest response times for Ethernet applications (approximately 5 to 8 ms). Three different types of response time scenarios are presented.

What's in this Section?

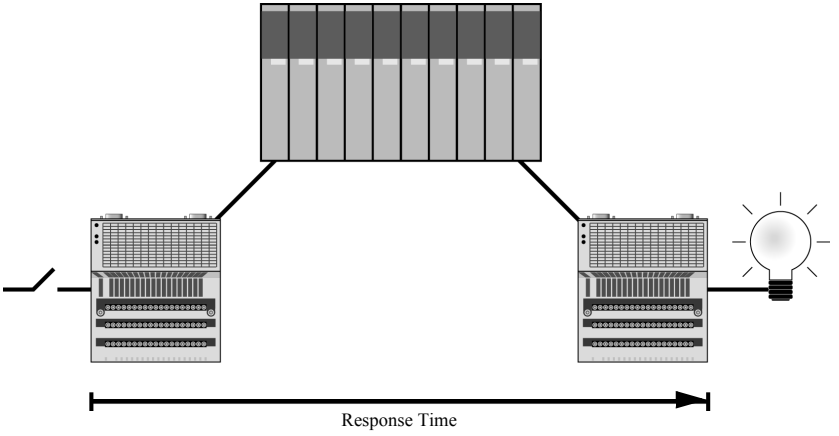
This section contains the following topics:

Topic	Page
Quantum I/O Scanner Response Tmes: Remote Input to Remote Output	388
Quantum I/O Scanner Response Tmes: Remote Input to Local Output	392
Quantum I/O Scanner Response Times: Local Input to Remote Output	396

Quantum I/O Scanner Response Tmes: Remote Input to Remote Output

Measurement Setup

The set of curves below illustrates Quantum PLC response times when a signal is sent from a remote input module through the PLC to a remote output module:



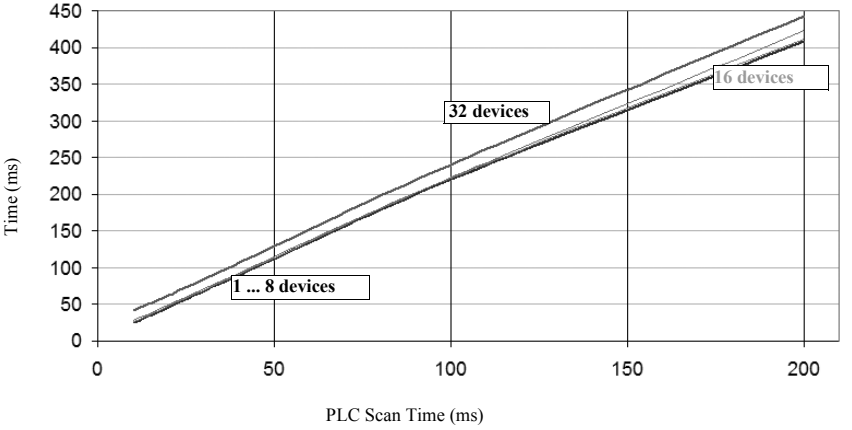
The signal is:

- triggered by a Momentum input module with a response time of ~2 ms
- scanned into the Quantum PLC at a repetition rate of 0 ms (see *p. 174*)
- copied to another internal variable within the PLC
- written to a Momentum output module with a response time of ~2 ms

Results are plotted for 1, 8, 16 and 32 devices.

140CPU65150 with Embedded Ethernet Port

The 140CPU65150 used for the following measurements is at version 2.0, with an embedded Ethernet port at version 3.1.



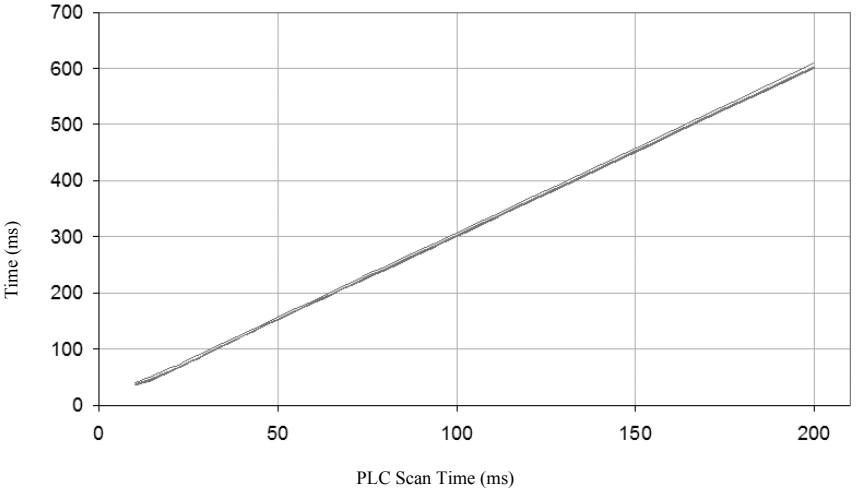
The bottom curve shows that the response times for 1 to 8 devices are within 1 to 3 ms of each other. The response times for 16 devices are 2 to 4 ms longer initially; as scan time increases, the difference in response times becomes larger (e.g., 11 ms at a 200 ms scan rate). The response times for 32 devices are 13 to 17 ms longer initially; as scan time increases, the difference in response times becomes larger (e.g., 34 ms more at a 200 ms scan).

The table below shows the data points used to generate the graph represented above.

Number of Devices to Scan	**Time from Scanned Device Input to Scanned Device Output (ms)**				
140CPU65150 (v2.0) + Embedded Ethernet Port (v3.1)	**10 ms Scan**	**20 ms Scan**	**50 ms Scan**	**100 ms Scan**	**200 ms Scan**
1 device	25	46	112	220	409
8 devices	26	47	113	222	412
16 devices	28	49	115	223	423
32 devices	42	62	129	241	443

140CPU65150 with 140NOE771x1 Module

The 140CPU65150 used for the following measurements is at version 2.0, and the 140NOE771x1 Ethernet communications module is at version 3.5.



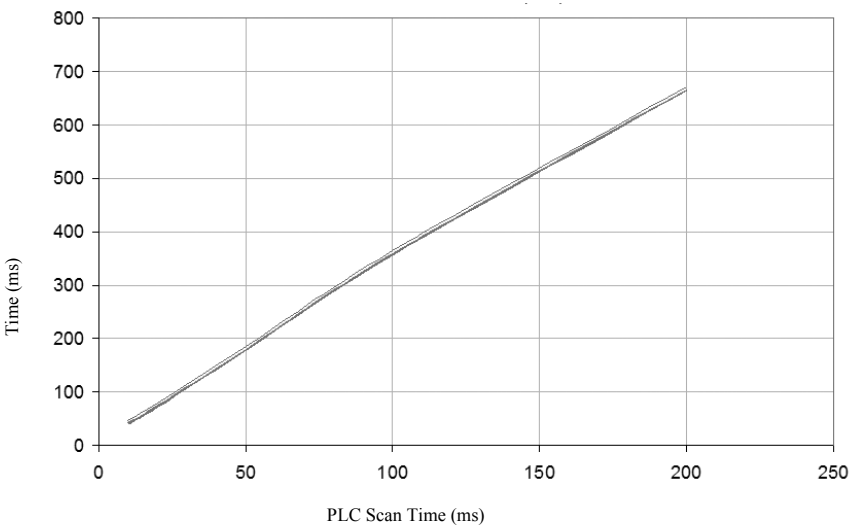
The curves above show that response times remain within 5 to 7 ms of each other whether 1, 8, 16 or 32 devices are used.

The table below shows the data points used to generate the graph represented above.

Number of Devices to Scan	**Time from Scanned Device Input to Scanned Device Output (ms)**				
140CPU65150 (v2.0) + NOE771x1 (v3.5)	**10 ms Scan**	**20 ms Scan**	**50 ms Scan**	**100 ms Scan**	**200 ms Scan**
1 device	35	61	153	302	602
8 devices	36	62	154	303	603
16 devices	38	64	155	305	606
32 devices	40	66	157	307	609

140CPU43412A with an 140NOE771x1 Module

The 140CPU43412A used for the following measurements is at version 2.0, and the 140NOE771x1 Ethernet communications module is at version 3.5.



The curves above show that response times remain within 5 to 6 ms of each other whether 1, 8, 16 or 32 devices are used.

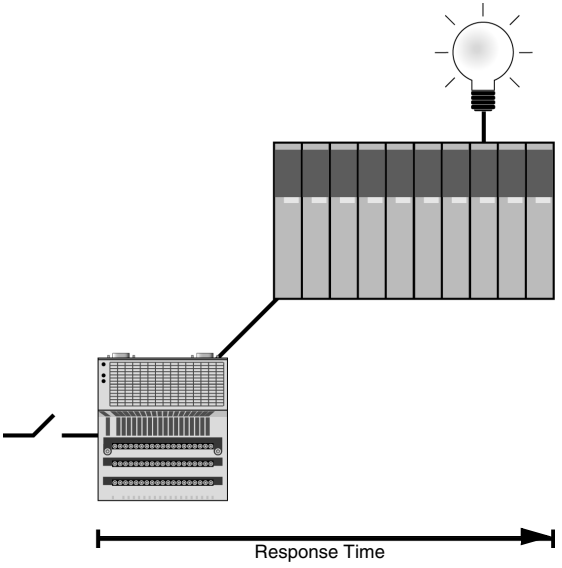
The table below shows the data points used to generate the graph represented above.

Number of Devices to Scan	Time from Scanned Device Input to Scanned Device Output (ms)				
140CPU43412A (v2.0) + NOE771x1 (v3.5)	**10 ms Scan**	**20 ms Scan**	**50 ms Scan**	**100 ms Scan**	**200 ms Scan**
1 device	41	73	179	358	665
8 devices	42	75	180	360	666
16 devices	44	77	182	361	668
32 devices	46	79	185	364	671

Quantum I/O Scanner Response Tmes: Remote Input to Local Output

Measurement Setup

The curves below illustrate the Quantum PLC response times when a signal is sent from a remote input module to a local output module in the PLC:



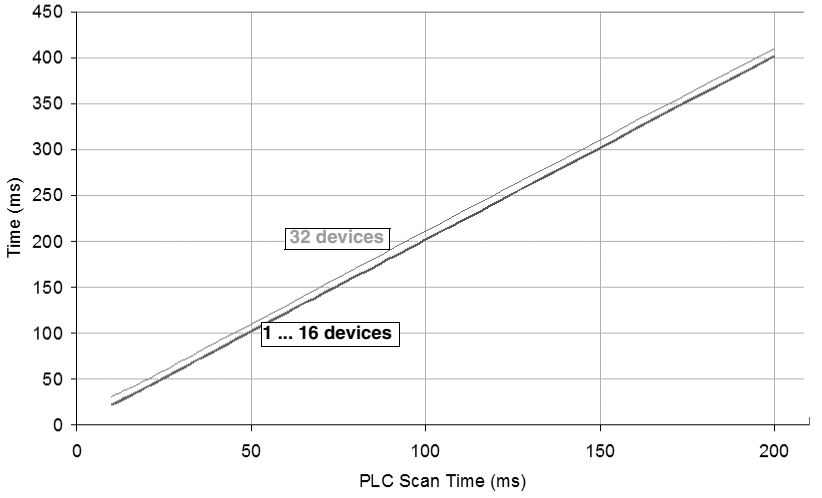
The signal is:

- triggered by a Momentum input module with a response time of ~2 ms
- scanned into the Quantum PLC at a repetition rate of 0 ms (see *p. 174*)
- copied to another internal variable within the PLC
- written to a local Quantum output module

Results are plotted for 1, 8, 16 and 32 devices.

140CPU65150 with Embedded Ethernet Port

The 140CPU65150 used for the following measurements is at version 2.0, with an embedded Ethernet port at version 3.1.



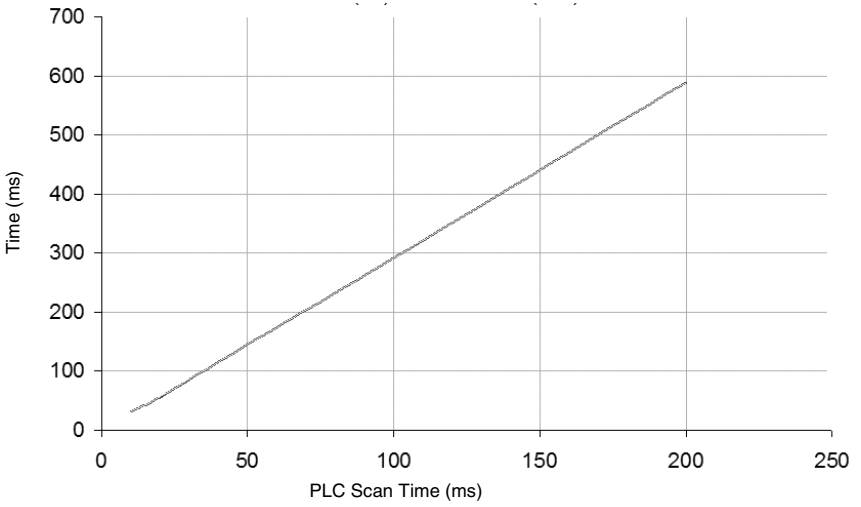
The lower curve shows that the response times for 1 to 16 devices remain within 2 ms of each other regardless of the PLC scan time. The upper curve shows that the response times for 32 devices are 7 to 8 ms greater.

The table below shows the data points used to generate the graph represented above.

Number of Devices to Scan	**Time from Scanned Device Input to Local Output (ms)**				
140CPU65150 (v2.0) + Embedded Ethernet Port (v3.1)	**10 ms Scan**	**20 ms Scan**	**50 ms Scan**	**100 ms Scan**	**200 ms Scan**
1 device	22	41	102	202	402
8 devices	23	42	103	204	403
16 devices	24	43	104	204	404
32 devices	31	49	110	211	410

140CPU65150 with 140NOE771x1 Module

The 140CPU65150 used for the following measurements is at version 2.0, with a 140NOE771x1 Ethernet communications module at version 3.5.



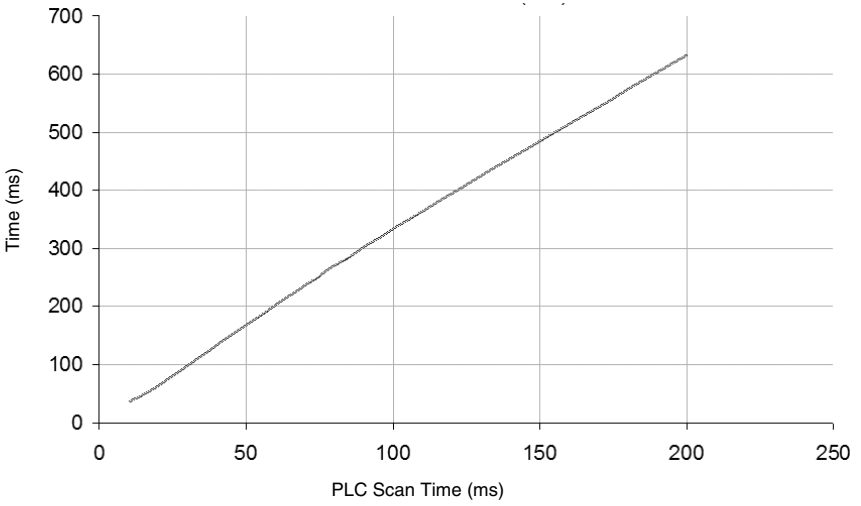
The curves above show that the response times for all devices remain are the same for 1, 8, 16 and 32 devices.

The table below shows the data points used to generate the graph represented above.

Number of Devices to Scan	**Time from Scanned Device Input to Local Output (ms)**				
140CPU65150 (v2.0) + NOE771x1 (v3.5)	**10 ms Scan**	**20 ms Scan**	**50 ms Scan**	**100 ms Scan**	**200 ms Scan**
1 device	31	56	145	292	590
8 devices	31	56	145	292	590
16 devices	31	56	145	292	590
32 devices	31	56	145	292	590

140CPU43412A with 140NOE771x1 Module

The 140CPU43412A used for the following measurements is at version 2.0, with a 140NOE771x1 Ethernet communications module at version 3.5.



The curves above show that the response times for all devices remain are the same for 1, 8, 16 and 32 devices.

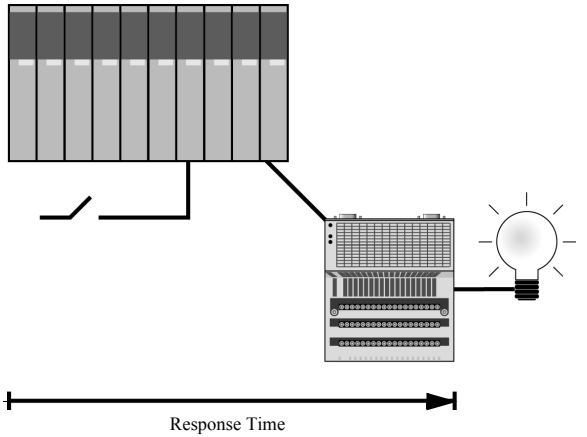
The table below shows the data points used to generate the graph represented above.

Number of Devices to Scan	**Time from Scanned Device Input to Local Output (ms)**				
140CPU43412A (v2.0) + NOE771x1 (v3.5)	**10 ms Scan**	**20 ms Scan**	**50 ms Scan**	**100 ms Scan**	**200 ms Scan**
1 device	35	64	168	334	634
8 devices	35	64	168	334	634
16 devices	35	64	168	334	634
32 devices	35	64	168	334	634

Quantum I/O Scanner Response Times: Local Input to Remote Output

Measurement Setup

The curves below illustrate the Quantum PLC response times for a when a signal is sent from the local PLC to a remote output module:



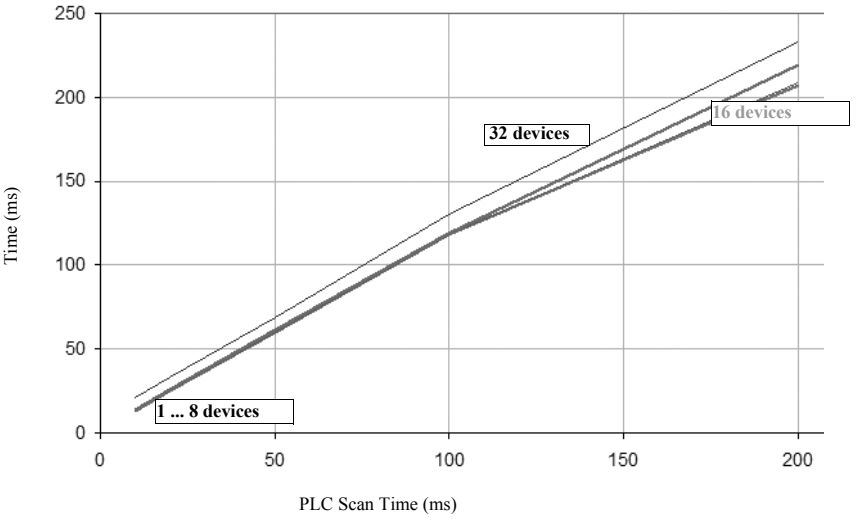
The signal is:

- triggered by a local Quantum input module
- scanned into the Quantum PLC at a repetition rate of 0 ms (see *p. 174*)
- copied to another internal variable within the PLC
- written to a remote Momentum output module with a response time of ~2 ms

Results are plotted for 1, 8, 16 and 32 devices.

140CPU65150 with Embedded Ethernet Port

The 140CPU65150 used for the following measurements is at version 2.0, with its embedded Ethernet port at version 3.1.



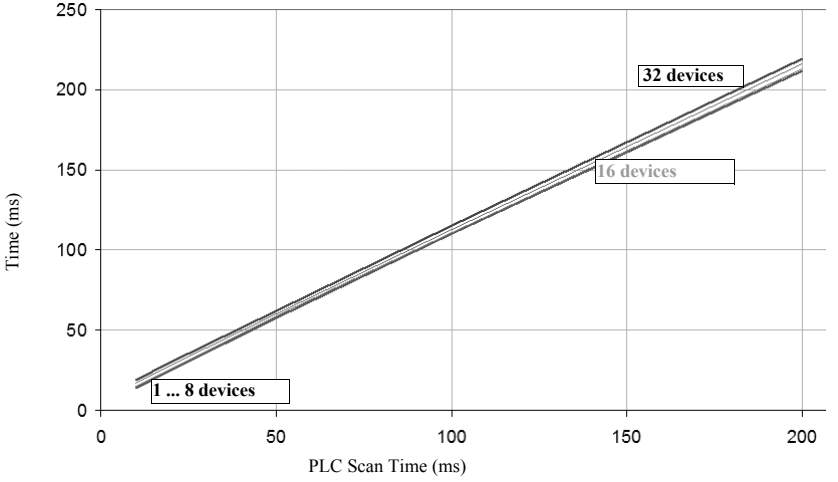
The bottom curve shows that the response times for 1 to 8 devices are almost the same, differing by only 2 ms at a 200 ms scan time. The response times for 16 devices are 1 ms longer initially; as scan time increases, the difference in response times increases to 10 to 12 ms at a 200 ms scan rate. The response times for 32 devices are 7 to 8 ms longer initially; as scan time increases, the difference in response times becomes larger (e.g., 14 to 16 ms more at a 200 ms scan).

The table below shows the data points used to generate the graph represented above.

Number of Devices to Scan	Time from Scanned Device Input to Local Output (ms)				
140CPU65150 (v2.0) + Embedded Ethernet Port (v3.1)	**10 ms Scan**	**20 ms Scan**	**50 ms Scan**	**100 ms Scan**	**200 ms Scan**
1 device	13	25	60	118	207
8 devices	13	25	60	118	209
16 devices	14	26	61	119	219
32 devices	21	33	69	130	233

140CPU65150 with 140NOE771x1 Ethernet Module

The 140CPU65150 used for the following measurements is at version 2.0, with a 140NOE771x1 Ethernet communications module at version 3.5.



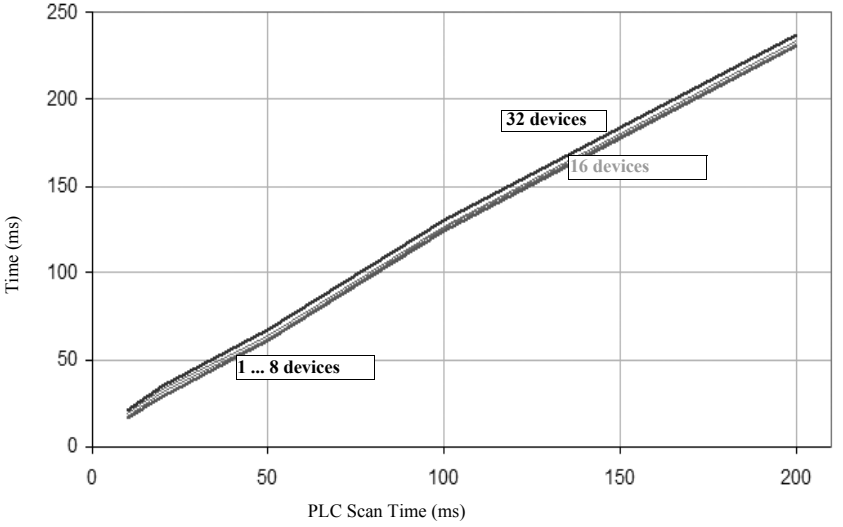
The curves above show that the response times for all devices remain within 5 to 7 ms of each other for 1, 8, 16 and 32 devices.

The table below shows the data points used to generate the graph represented above.

Number of Devices to Scan	Time from Scanned Device Input to Local Output (ms)				
140CPU65150 (v2.0) + NOE771x1 (v3.5)	10 ms Scan	20 ms Scan	50 ms Scan	100 ms Scan	200 ms Scan
1 device	14	25	58	110	212
8 devices	15	26	59	111	213
16 devices	17	28	60	113	216
32 devices	19	30	62	115	219

140CPU43412A with 140NOE771x1 Ethernet Module

The 140CPU43412A used for the following measurements is at version 2.0, with a 140NOE771x1 Ethernet communications module at version 3.5.



The curves above show that the response times for all devices remain within 5 to 6 ms of each other for 1, 8, 16 and 32 devices.

The table below shows the data points used to generate the graph represented above.

Number of Devices to Scan	Time from Scanned Device Input to Local Output (ms)				
140CPU43412A (v2.0) + NOE771x1 (v3.5)	**10 ms Scan**	**20 ms Scan**	**50 ms Scan**	**100 ms Scan**	**200 ms Scan**
1 device	16	29	61	124	231
8 devices	17	31	62	126	232
16 devices	19	33	64	127	234
32 devices	21	35	67	130	237

Modbus Server Throughput Capacity

B

At a Glance

Overview

This appendix illustrates Modbus server throughput for Premium and Quantum systems that use industrial Ethernet.

What's in this Chapter?

This chapter contains the following topics:

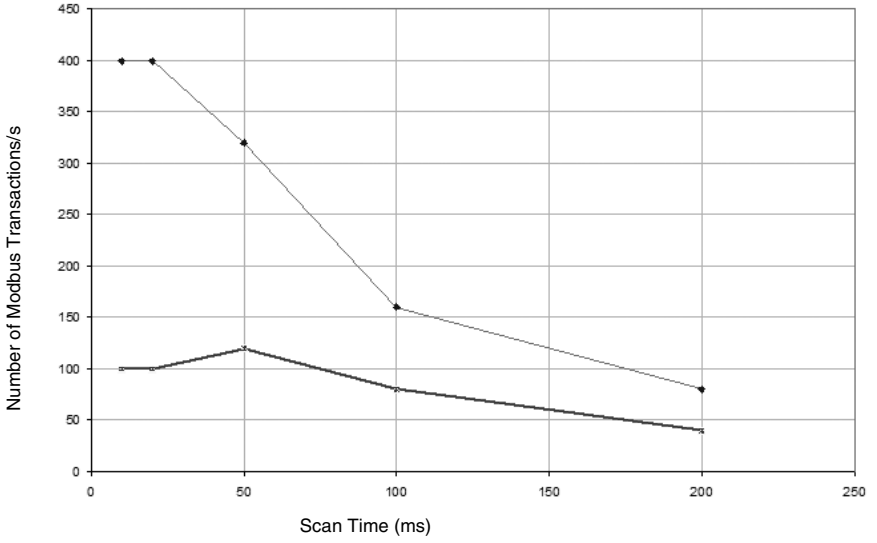
Topic	Page
Quantum Modbus Server Throughput Capacity: Unity v2.0	402
Premium Modbus Server Throughput Capacity: Unity v2.0	404

Quantum Modbus Server Throughput Capacity: Unity v2.0

Performance Measurements

The following chart shows the number of Modbus read-register requests that may be answered by Quantum CPUs in 1 s. (A read-register request is a Modbus function code 3 command.) The minimum time to respond to a single Modbus request is one PLC scan cycle. The throughput capacity of five systems is measured:

- a 140CPU65150 with a 140NOE77101Ethernet communications module
- a 140CPU65150 with a 140NOE77111 Ethernet communications module
- a 140CPU43412A with a 140NOE77101Ethernet communications module
- a 140CPU43412A with a 140NOE77111Ethernet communications module
- a 140CPU65150 with an embedded Ethernet port



The four bottom curves (all with equal values and hence appearing as one line) show throughput for the four CPUs that use NOE modules. The upper curve shows throughput for the CPU with an embedded Ethernet port. As scan times increase, the difference in throughput capacity (the number of Modbus transactions/ messages) between the CPUs with NOE modules and the CPU with the Embedded Ethernet port decreases.

The table below shows the data points used to generate the graph represented above.

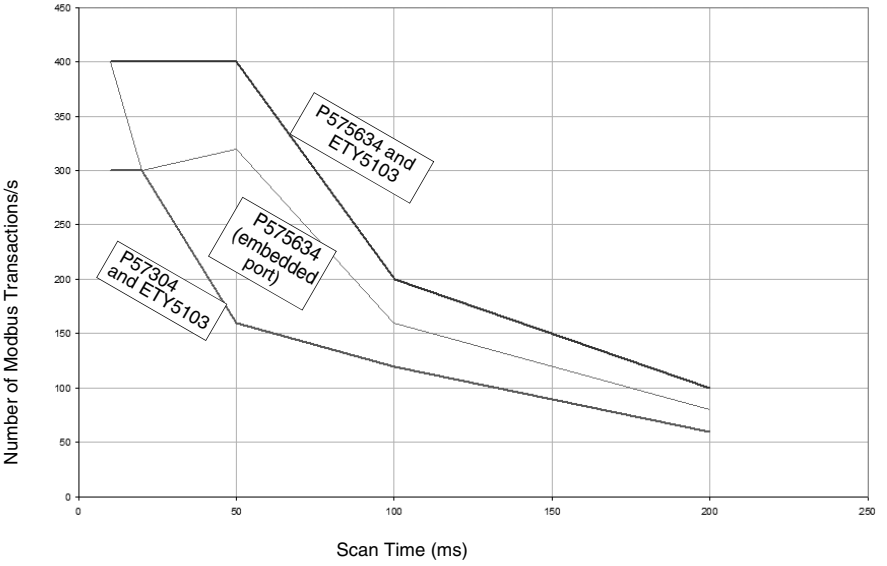
Scan TIme (ms)	65150 (Embedded Port)	65150 + NOE77101	65150 + NOE77111	43412A + NOE77101	43412A+ NOE77111
Scan Time	**Number of Modbus Transactions/Second**				
10	400	100	100	100	100
20	400	100	100	100	100
50	320	120	120	120	120
100	160	80	80	80	80
200	80	40	40	40	40

Premium Modbus Server Throughput Capacity: Unity v2.0

Performance Measurements

The following chart shows the number of Modbus read-register requests that may be answered by Premium CPUs in 1 CPU scan. (A read-register request is a Modbus function code 3 command.) The minimum time to respond to a single Modbus request is one PLC scan cycle. The throughput capacity of three PLCs is measured:

- a TSXP575634M CPU with a TSX ETY5103 Ethernet communications module
- a TSXP575634M CPU with an embedded Ethernet port
- a TSXP57304M CPU with a TSX ETY5103 Ethernet communications module



The table below shows the data points used to generate the graph represented above.

	P575634M (Embedded Port)	**P575634M + ETY5103**	**P57304M + ETY5103**
Scan Time	**Number of Modbus Transactions/Second**		
10	400	400	300
20	300	400	300
50	320	400	160
100	160	200	120
200	80	100	60

Modbus Client Response Times

C

At a Glance

Overview

This appendix illustrates some Modbus client response times for Premium and Quantum systems that use industrial Ethernet.

What's in this Chapter?

This chapter contains the following topics:

Topic	Page
Modbus Client Response Times: Premium TSXP575634M	406
Modbus Client Response Times: Premium TSXP57304M	413
Modbus Client Response Times: Quantum 140 CPU65150 with an Embedded Ethernet Port	420
Modbus Client Response Times: Quantum 140 CPU65150 with a 140 NOE77101 Ethernet Communications Module	425
Modbus Client Response Times: Quantum 140 CPU65150 with a 140 NOE77111 Ethernet Communications Module	430
Modbus Client Response Times: Quantum 140 CPU43412A with a 140 NOE77101 Ethernet Communications Module	435
Modbus Client Response Times: Quantum 140 CPU43412A with a 140 NOE77111 Ethernet Communications Module	440

Modbus Client Response Times: Premium TSXP575634M

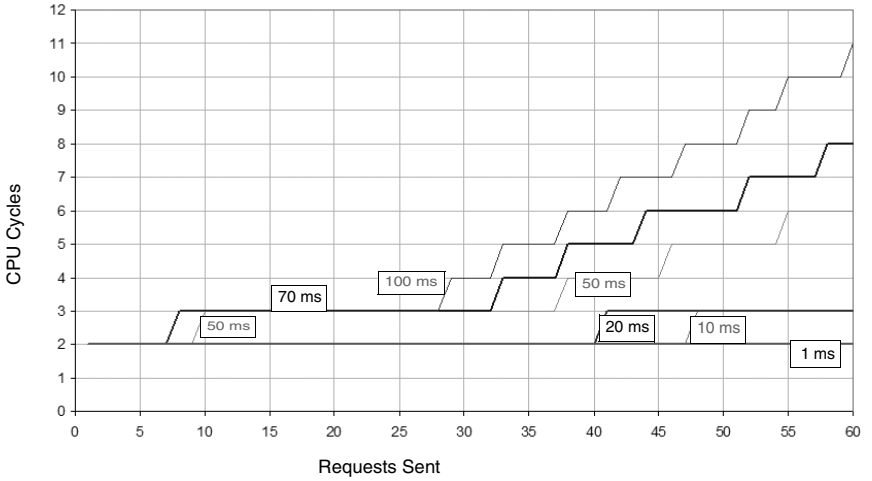
Test Setup

The following charts show Premium CPU response times where a client request block is triggered in PLC logic by reading data from a Modbus server. The graphs represent the number of CPU cycles required for the PLC to complete all triggered Modbus client requests. In all cases, the CPU is a Premium TSXP575634M with an TSXETY5103 Ethernet communications module (exec v3.10). The CPU logic scan times vary.

Modbus client response times are tracked with respect to six Modbus server response times:

- < 1 ms
- 10 ms
- 20 ms
- 50 ms
- 70 ms
- 100 ms

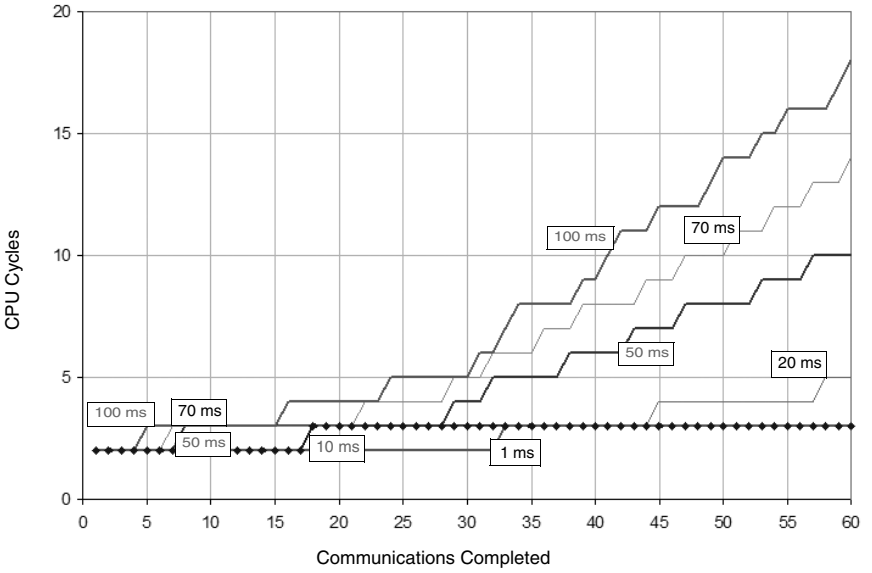
at a CPU Scan Time of 200 ms



A sampling of results in the chart follows:

Number of Requests	Server Response Time	CPU Cycles Needed To Complete
1 ... 7	<1 ... 100 ms	2 cycles
8	70 ... 100 ms	3 cycles
10	50 ms	3 cycles
29	100 ms	4 cycles
33	70 ms	4 cycles
	100 ms	5 cycles
38	50 ms	4 cycles
	70 ms	5 cycles
	100 ms	6 cycles
41	20 ms	3 cycles
42	100 ms	7 cycles
46	50 ms	5 cycles
	70 ms	6 cycles
48	10 ms	3 cycles
55	50 ms	6 cycles
	70 ms	7 cycles
	100 ms	10 cycles
60	100 ms	11 cycles

at a CPU Scan Time of 100 ms

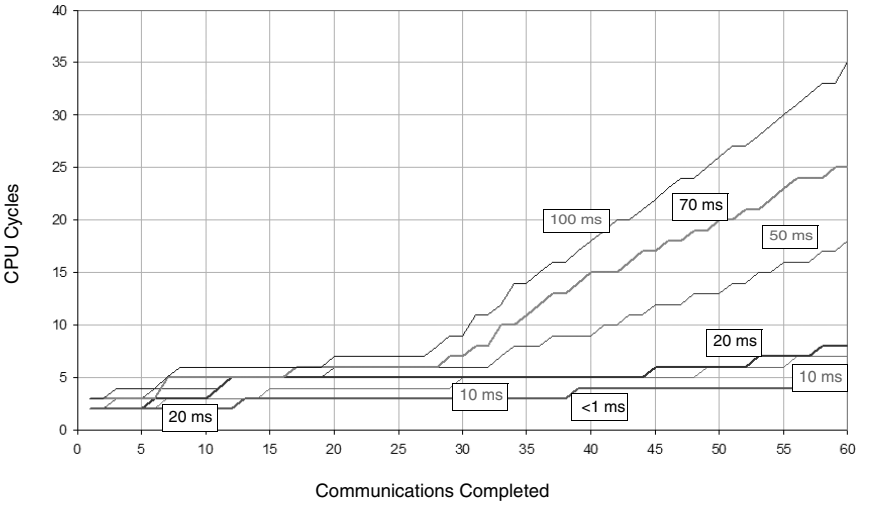


A sampling of results in the chart follows:

Number of Requests	Server Response Time	CPU Cycles Needed To Complete
1 ... 4	<1 ... 100 ms	2 cycles
5	100 ms	3 cycles
7	20 ... 70 ms	3 cycles
16	100 ms	4 cycles
18	10 ms	3 cycles
22	70 ms	4 cycles
24	100 ms	5 cycles
29	50 ms	4 cycles
	70 ms	5 cycles
31	100 ms	6 cycles
33	<1 ms	3 cycles
	70 ms	6 cycles
	100 ms	7 cycles
34	100 ms	8 cycles
38	50 ms	6 cycles
39	70 ms	8 cycles
	100 ms	9 cycles

Number of Requests	Server Response Time	CPU Cycles Needed To Complete
47	20 ms	4 cycles
	50 ms	8 cycles
	70 ms	10 cycles
	100 ms	12 cycles
60	20 ms	5 cycles
	50 ms	10 cycles
	70 ms	14 cycles
	100 ms	18 cycles

at a CPU Scan Time of 50 ms

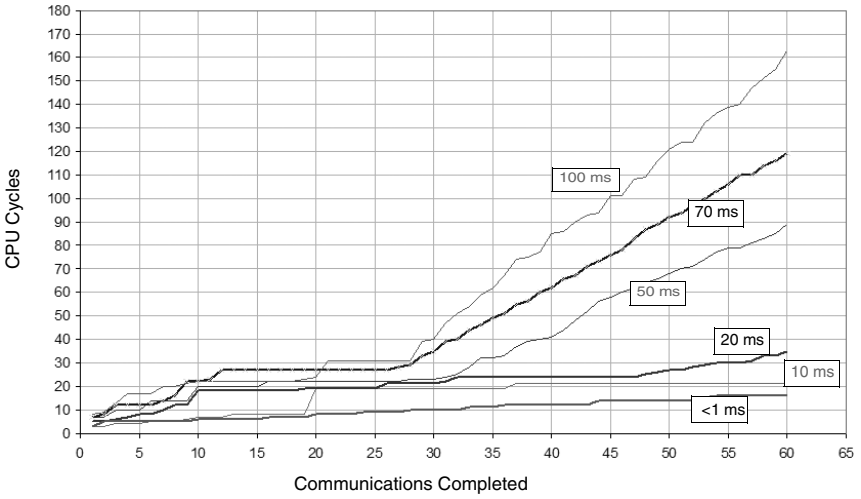


A sampling of results in the chart follows:

Number of Requests	Server Response Time	CPU Cycles Needed To Complete
1 ... 2	<1 ... 50 ms	2 cycles
	70 ... 100 ms	3 cycles
3	50 ms	3 cycles
	100 ms	4 cycles
7	10 ... 20 ms	3 cycles
	50 ms	4 cycles
	70 ... 100 ms	5 cycles
8	100 ms	6 cycles

Number of Requests	Server Response Time	CPU Cycles Needed To Complete
15	10 ms	4 cycles
	20 ... 70 ms	5 cycles
26	50 ... 70 ms	6 cycles
	100 ms	7 cycles
31	70 ms	8 cycles
	100 ms	11 cycles
37	50 ms	9 cycles
	70 ms	13 cycles
	100 ms	16 cycles
39	<1 ms	4 cycles
	100 ms	17 cycles
50	10 ... 20 ms	6 cycles
	50 ms	13 cycles
	70 ms	20 cycles
	100 ms	26 cycles
60	<1 ms	5 cycles
	10 ms	7 cycles
	20 ms	8 cycles
	50 ms	18 cycles
	70 ms	25 cycles
	100 ms	35 cycles

at a CPU Scan Time of 10 ms



A sampling of results in the chart follows:

Number of Requests	Server Response Time	CPU Cycles Needed To Complete
1	<1 ... 10 ms	3 cycles
	20 ms	5 cycles
	50 ... 70 ms	7 cycles
	100 ms	8 cycles
3	<1 ms	5 cycles
	10 ms	4 cycles
	20 ms	6 cycles
	50 ms	10 cycles
	70 ms	12 cycles
	100 ms	13 cycles
10	<1 ms	6 cycles
	10 ms	7 cycles
	20 ms	18 cycles
	70 ... 100 ms	22 ms

Number of Requests	Server Response Time	CPU Cycles Needed To Complete
16	10 ms	8 cycles
	20 ms	18 cycles
	50 ms	22 cycles
	70 ms	27 cycles
	100 ms	22 cycles
21	<1 ms	8 cycles
	10 ... 20 ms	19 cycles
	50 ms	22 cycles
	70 ms	27 cycles
	100 ms	31 cycles
33	<1 ms	11 cycles
	10 ms	19 cycles
	20 ms	24 cycles
	50 ms	25 cycles
	70 ms	44 cycles
	100 ms	54 cycles
39	<1 ms	4 cycles
	100 ms	17 cycles
45	<1 ms	14 cycles
	10 ms	21 cycles
	50 ms	58 cycles
	70 ms	76 cycles
	100 ms	101 cycles
60	<1 ms	16 cycles
	10 ms	21 cycles
	20 ms	35 cycles
	50 ms	89 cycles
	70 ms	119 cycles
	100 ms	163 cycles

Modbus Client Response Times: Premium TSXP57304M

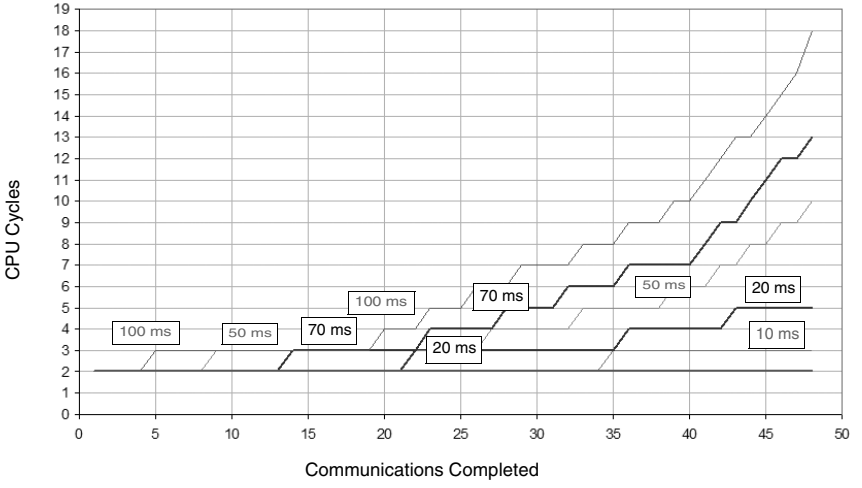
Test Setup

The following charts show Premium CPU response times where the client request block is triggered in PLC logic by reading data from a Modbus server. The graphs represent the number of CPU cycles required for the PLC to complete all triggered Modbus client requests. In all cases, the PLC is a Premium TSXP57304M with an ETY5103 Ethernet communications module (exec v3.10). The CPU logic scan times vary.

Modbus client response times are tracked with respect to six Modbus server response times:

- < 1 ms
- 10 ms
- 20 ms
- 50 ms
- 70 ms
- 100 ms

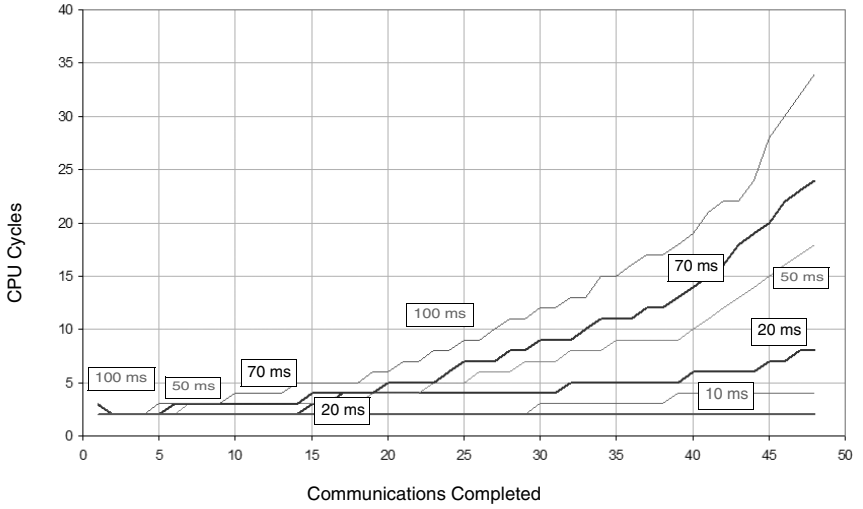
at a CPU Scan Time of 200 ms



A sampling of results in the chart follows:

Number of Requests	Server Response Time	CPU Cycles Needed To Complete
1 ... 4	<1 ... 100 ms	2 cycles
5	100 ms	3 cycles
9	50 ms	3 cycles
14	70 ms	3 cycles
20	100 ms	4 cycles
23	20 ms	3 cycles
	70 ms	4 cycles
	100 ms	5 cycles
28	50 ms	4 cycles
	70 ms	5 cycles
	100 ms	6 cycles
36	10 ms	3 cycles
	20 ms	4 cycles
	50 ms	5 cycles
	70 ms	7 cycles
	100 ms	9 cycles
43	20 ms	5 cycles
	50 ms	7 cycles
	70 ms	9 cycles
	100 ms	13 cycles
48	50 ms	10 cycles
	70 ms	13 cycles
	100 ms	18 cycles

at a CPU Scan Time of 100 ms

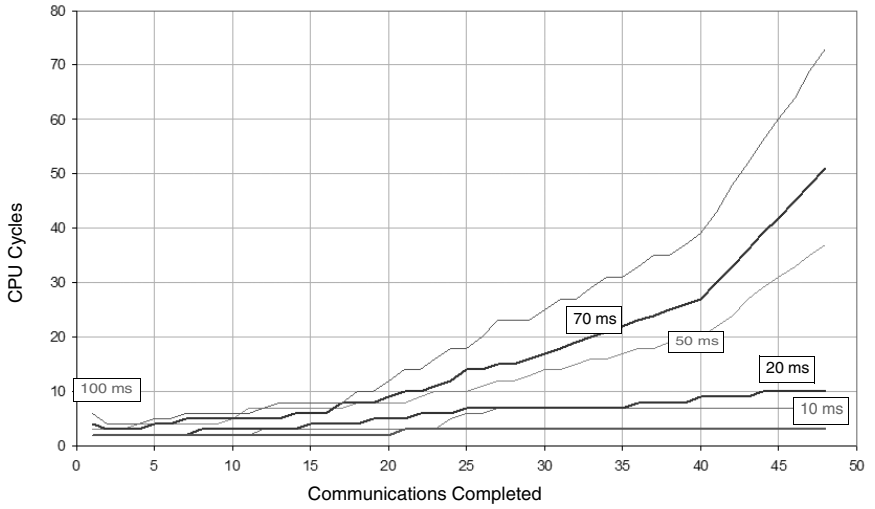


A sampling of results in the chart follows:

Number of Requests	Server Response Time	CPU Cycles Needed To Complete
1	<1 ... 50 ms	2 cycles
	70 ... 100 ms	3 cycles
2 ... 4	<1 ... 100 ms	2 cycles
5	100 ms	3 cycles
6	50 ... 70 ms	3 cycles
15	20 ... 50 ms	3 cycles
	70 ms	3 cycles
	100 ms	5 cycles
18	20 ms	4 cycles
	50 ms	3 cycles
	70 ms	4 cycles
24	50 ms	5 cycles
	70 ms	3 cycles
	100 ms	5 cycles

Number of Requests	Server Response Time	CPU Cycles Needed To Complete
32	10 ms	3 cycles
	20 ms	5 cycles
	50 ms	8 cycles
	70 ms	9 cycles
	100 ms	13 cycles
48	10 ms	4 cycles
	20 ms	8 cycles
	50 ms	18 cycles
	70 ms	24 cycles
	100 ms	34 cycles

at a CPU Scan Time of 50 ms

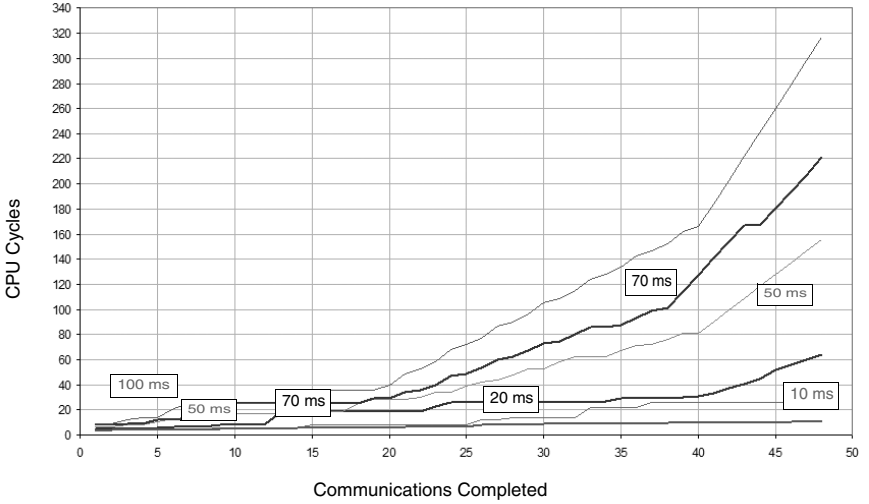


A sampling of results in the chart follows:

Number of Requests	Server Response Time	CPU Cycles Needed To Complete
1	<1 ... 20 ms	2 cycles
	50 ms	3 cycles
	70 ms	4 cycles
	100 ms	6 cycles
2	70 ms	3 cycles
	100 ms	4 cycles

Number of Requests	Server Response Time	CPU Cycles Needed To Complete
4	50 ms	4 cycles
8	20 ms	3 cycles
	70 ms	5 cycles
	100 ms	6 cycles
15	10 ms	3 cycles
	20 ms	4 cycles
	50 ms	7 cycles
	70 ms	6 cycles
	100 ms	8 cycles
22	<1 ms	3 cycles
	20 ms	6 cycles
	50 ms	9 cycles
	70 ms	10 cycles
	100 ms	14 cycles
35	10 ... 20 ms	7 cycles
	50 ms	17 cycles
	70 ms	22 cycles
	100 ms	31 cycles
48	20 ms	10 cycles
	50 ms	37 cycles
	70 ms	51 cycles
	100 ms	73 cycles

at a CPU Scan Time of 10 ms



A sampling of results in the chart follows:

Number of Requests	Server Response Time	CPU Cycles Needed To Complete
1	<1 ... 10 ms	2 cycles
	20 ms	4 cycles
	50 ms	5 cycles
	70 ms	3 cycles
	100 ms	5 cycles
2	10 ms	3 cycles
3	<1 ms	3 cycles
	70 ms	4 cycles
	100 ms	6 cycles
11	<1 ms	4 cycles
	10 ms	5 cycles
	20 ms	6 cycles
	50 ms	15 cycles
	70 ms	12 cycles
	100 ms	22 cycles

Number of Requests	Server Response Time	CPU Cycles Needed To Complete
18	<1 ms	5 cycles
	10 ms	6 cycles
	20 ms	13 cycles
	50 ms	16 cycles
	70 ms	22 cycles
	100 ms	28 cycles
22	<1 ms	6 cycles
	10 ms	7 cycles
	20 ms	18 cycles
	50 ms	27 cycles
	70 ms	35 cycles
	100 ms	50 cycles
39	<1 ms	9 cycles
	10 ms	12 cycles
	20 ms	33 cycles
	50 ms	81 cycles
	70 ms	109 cycles
	100 ms	159 cycles
48	<1 ms	10 cycles
	20 ms	16 cycles
	20 ms	64 cycles
	50 ms	159 cycles
	70 ms	220 cycles
	100 ms	314 cycles

Modbus Client Response Times: Quantum 140 CPU65150 with an Embedded Ethernet Port

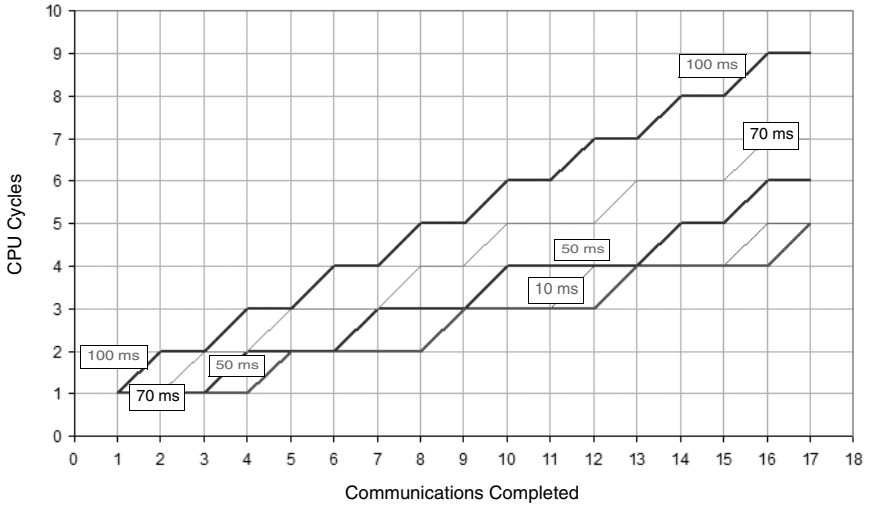
Test Setup

The following charts show Quantum PLC response times where the client request block is triggered in PLC logic by reading data from a Modbus server. The graphs represent the number of CPU cycles required for the PLC to complete all triggered Modbus client requests. In all cases, the PLC is a Quantum 140 CPU65150 with an embedded Ethernet port. The CPU logic scan times vary.

Modbus client response times are tracked with respect to six Modbus server response times:

- < 1 ms
- 10 ms
- 20 ms
- 50 ms
- 70 ms
- 100 ms

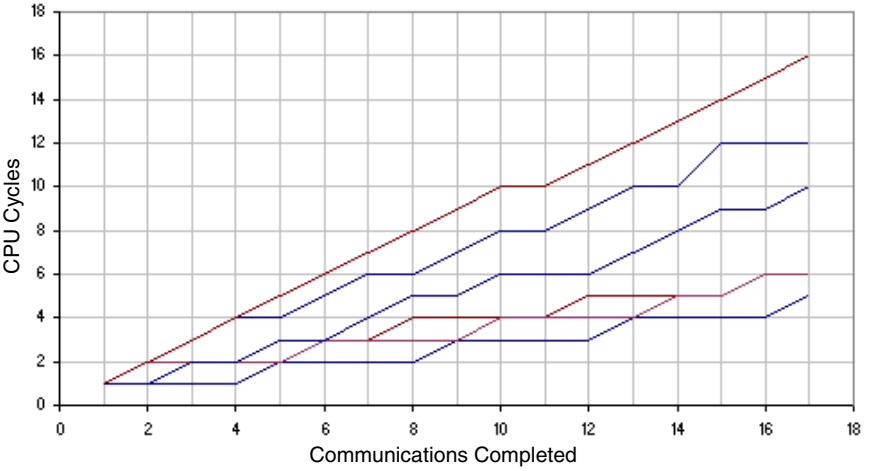
At a CPU Scan Time of 200 ms



The table below shows the data points used to generate the graph represented above.

PLC Scan (ms)	Server Response Time (ms)					
200	**<1**	**10**	**20**	**50**	**70**	**100**
Requests Sent	**PLC Cycles to Receive Response**					
1	1	1	1	1	1	1
2	1	1	1	1	1	2
3	1	1	1	1	2	2
4	1	1	1	2	2	3
5	2	2	2	2	3	3
6	2	2	2	2	3	4
7	2	2	2	3	3	4
8	2	2	2	3	4	5
9	3	3	3	3	4	5
10	3	3	3	4	5	6
11	3	3	3	4	5	6
12	3	4	3	4	5	7
13	4	4	4	4	6	7
14	4	4	4	5	6	8
15	4	4	4	5	6	8
16	4	5	4	6	7	9
17	5	5	5	6	7	9

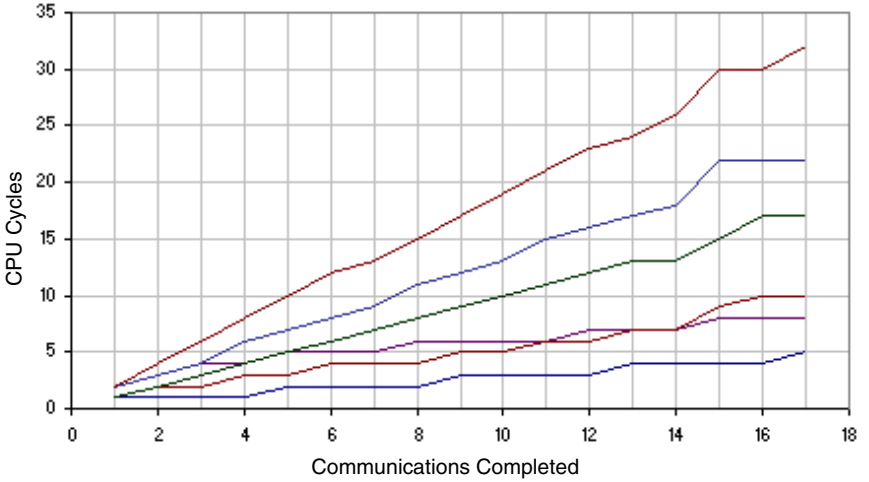
At a CPU Scan Time of 100 ms



The table below shows the data points used to generate the graph represented above.

PLC Scan (ms)	Server Response Time (ms)					
100	**<1**	**10**	**20**	**50**	**70**	**100**
Requests Sent	**PLC Cycles to Receive Response**					
1	1	1	1	1	1	1
2	1	2	2	1	2	2
3	1	2	2	2	3	3
4	1	2	2	2	4	4
5	2	2	2	3	4	5
6	2	3	3	3	5	6
7	2	3	3	4	6	7
8	2	4	3	5	6	8
9	3	4	3	5	7	9
10	3	4	4	6	8	10
11	3	4	4	6	8	10
12	3	5	4	6	9	11
13	4	5	4	7	10	12
14	4	5	5	8	10	13
15	4	5	5	9	12	14
16	4	6	6	9	12	15
17	5	6	6	10	12	16

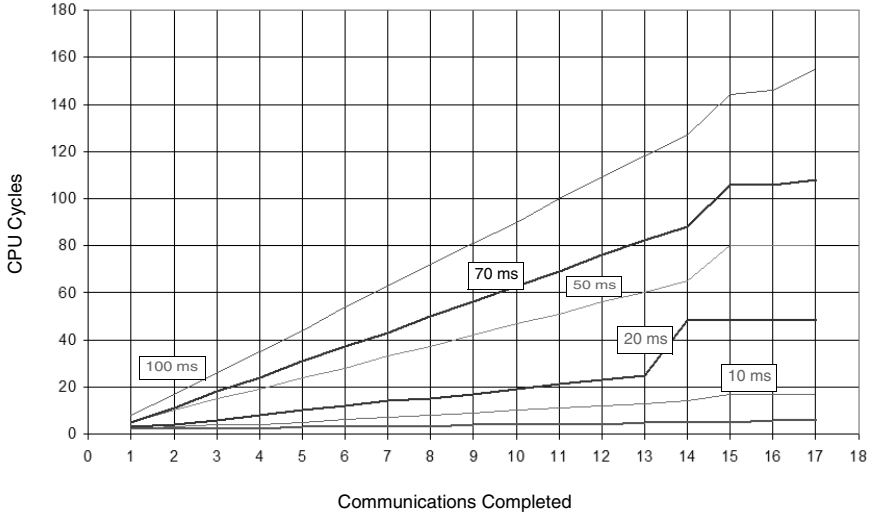
At a CPU Scan Time of 50 ms



The table below shows the data points used to generate the graph represented above.

PLC Scan (ms)	Server Response Time (ms)					
50	**<1**	**10**	**20**	**50**	**70**	**100**
Requests Sent	**PLC Cycles to Receive Response**					
1	1	2	1	1	2	2
2	1	3	2	2	3	4
3	1	4	2	3	4	6
4	1	4	3	4	6	8
5	2	5	3	5	7	10
6	2	5	4	6	8	12
7	2	5	4	7	9	13
8	2	6	4	8	11	15
9	3	6	5	9	12	17
10	3	6	5	10	13	19
11	3	6	6	11	15	21
12	3	7	6	12	16	23
13	4	7	7	13	17	24
14	4	7	7	13	18	26
15	4	8	9	15	22	30
16	4	8	10	17	22	30
17	5	8	10	17	22	32

At a CPU Scan Time of 10 ms



The table below shows the data points used to generate the graph represented above.

PLC Scan (ms)	**Server Response Time (ms)**					
10	**<1**	**10**	**20**	**50**	**70**	**100**
Requests Sent	**PLC Cycles to Receive Response**					
1	2	2	3	5	5	8
2	2	3	4	10	11	17
3	2	4	6	15	18	26
4	2	4	8	19	24	35
5	3	5	10	24	31	44
6	3	6	12	28	37	54
7	3	7	14	33	43	63
8	3	8	15	37	50	72
9	4	9	17	42	56	81
10	4	10	19	47	63	90
11	4	11	21	51	69	100
12	4	12	23	56	76	109
13	5	13	25	60	82	118
14	5	14	48	65	88	127
15	5	17	48	80	106	144
16	6	17	48	80	106	146
17	6	17	48	80	108	155

Modbus Client Response Times: Quantum 140 CPU65150 with a 140 NOE77101 Ethernet Communications Module

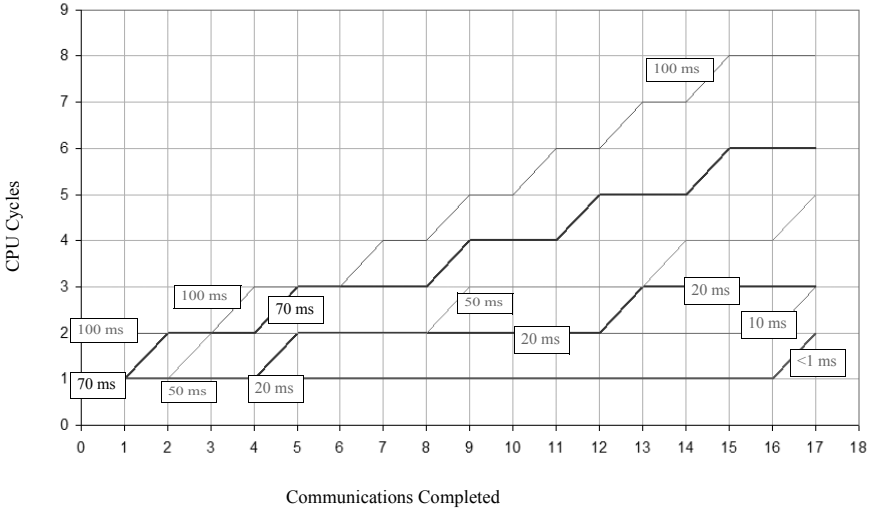
Test Setup

The following charts show Quantum PLC response times where the client request block is triggered in PLC logic by reading data from a Modbus server. The graphs represent the number of CPU cycles required for the PLC to complete all triggered Modbus client requests. In all cases, the PLC is a Quantum 140 CPU65150 with a 140 NOE77101 Ethernet communications module. The CPU logic scan times vary.

Modbus client response times are tracked with respect to six Modbus server response times:

- < 1 ms
- 10 ms
- 20 ms
- 50 ms
- 70 ms
- 100 ms

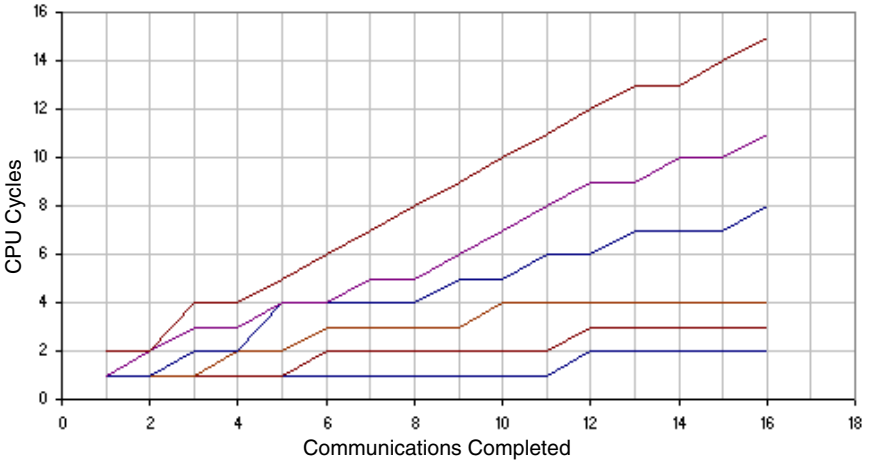
At a CPU Scan Time of 200 ms



The table below shows the data points used to generate the graph represented above.

PLC Scan (ms)	Server Response Time (ms)					
200	**<1**	**10**	**20**	**50**	**70**	**100**
Requests Sent	**PLC Cycles to Receive Response**					
1	1	1	1	1	1	2
2	1	1	1	1	2	2
3	1	1	1	2	2	2
4	1	1	1	2	2	3
5	1	2	2	2	3	3
6	1	2	2	2	3	3
7	1	2	2	2	3	4
8	1	2	2	2	3	4
9	1	2	2	3	4	5
10	1	2	2	3	4	5
11	1	2	2	3	4	6
12	1	2	2	3	5	6
13	1	2	3	3	5	7
14	1	2	3	4	5	7
15	1	2	3	4	6	8
16	1	2	3	4	6	8
17	2	3	3	5	6	8

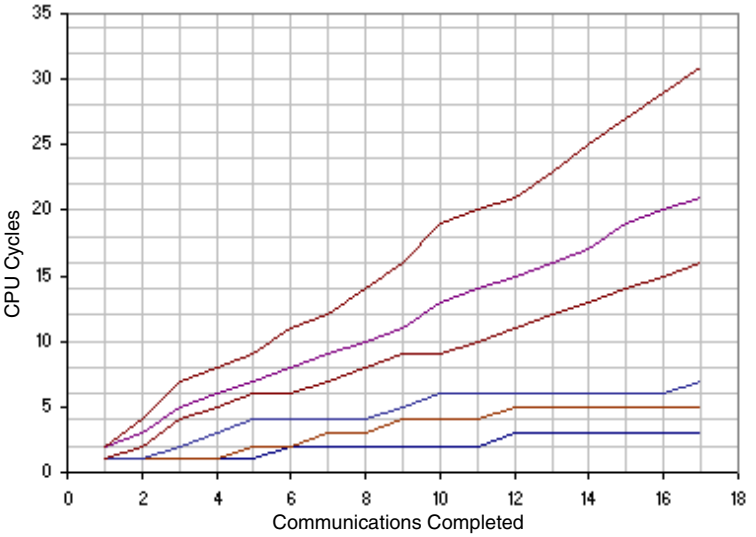
At a CPU Scan Time of 100 ms



The table below shows the data points used to generate the graph represented above.

PLC Scan (ms)	Server Response Time (ms)					
100	**<1**	**10**	**20**	**50**	**70**	**100**
Requests Sent	**PLC Cycles to Receive Response**					
1	1	1	1	1	1	2
2	1	1	1	1	2	2
3	1	1	1	2	3	4
4	1	1	2	2	3	4
5	1	1	2	4	4	5
6	1	2	3	4	4	6
7	1	2	3	4	5	7
8	1	2	3	4	5	8
9	1	2	3	5	6	9
10	1	2	4	5	7	10
11	1	2	4	6	8	11
12	2	3	4	6	9	12
13	2	3	4	7	9	13
14	2	3	4	7	10	13
15	2	3	4	7	10	14
16	2	3	4	8	11	15
17	2	3	4	8	11	16

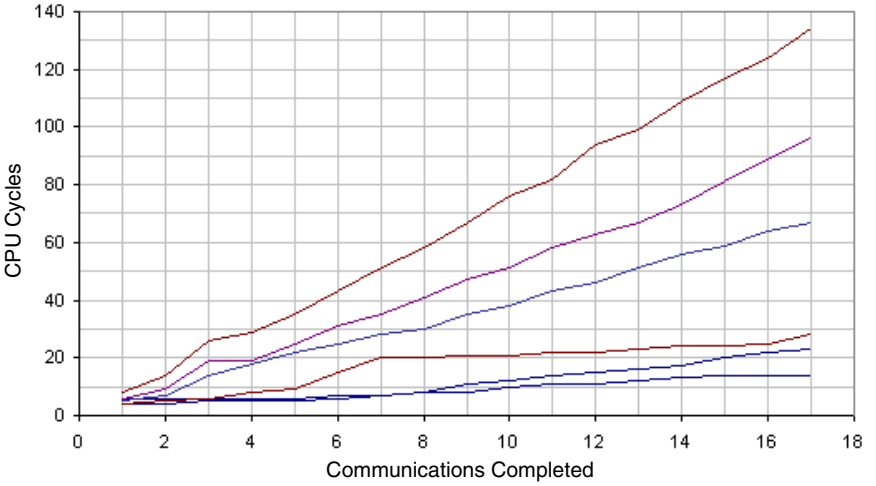
At a CPU Scan Time of 50 ms



The table below shows the data points used to generate the graph represented above.

PLC Scan (ms)	Server Response Time (ms)					
50	**<1**	**10**	**20**	**50**	**70**	**100**
Requests Sent	**PLC Cycles to Receive Response**					
1	1	1	1	1	2	2
2	1	1	1	2	3	4
3	1	1	2	4	5	7
4	1	1	3	5	6	8
5	1	2	4	6	7	9
6	2	2	4	6	8	11
7	2	3	4	7	9	12
8	2	3	4	8	10	14
9	2	4	5	9	11	16
10	2	4	6	9	13	19
11	2	4	6	10	14	20
12	3	5	6	11	15	21
13	3	5	6	12	16	23
14	3	5	6	13	17	25
15	3	5	6	14	19	27
16	3	5	6	15	20	29
17	3	5	7	16	21	31

At a CPU Scan Time of 10 ms



The table below shows the data points used to generate the graph represented above.

PLC Scan (ms)	Server Response Time (ms)					
10	**<1**	**10**	**20**	**50**	**70**	**100**
Requests Sent	**PLC Cycles to Receive Response**					
1	6	4	4	5	6	8
2	6	4	5	7	9	14
3	6	5	6	14	19	26
4	6	5	8	18	19	29
5	6	5	9	22	25	35
6	7	6	15	25	31	43
7	7	7	20	28	35	51
8	8	8	20	30	41	58
9	8	11	21	35	47	67
10	10	12	21	38	51	76
11	11	14	22	43	58	82
12	11	15	22	46	63	94
13	12	16	23	51	67	99
14	13	17	24	56	73	109
15	14	20	24	59	81	117
16	14	22	25	64	89	124
17	14	23	28	67	96	134

Modbus Client Response Times: Quantum 140 CPU65150 with a 140 NOE77111 Ethernet Communications Module

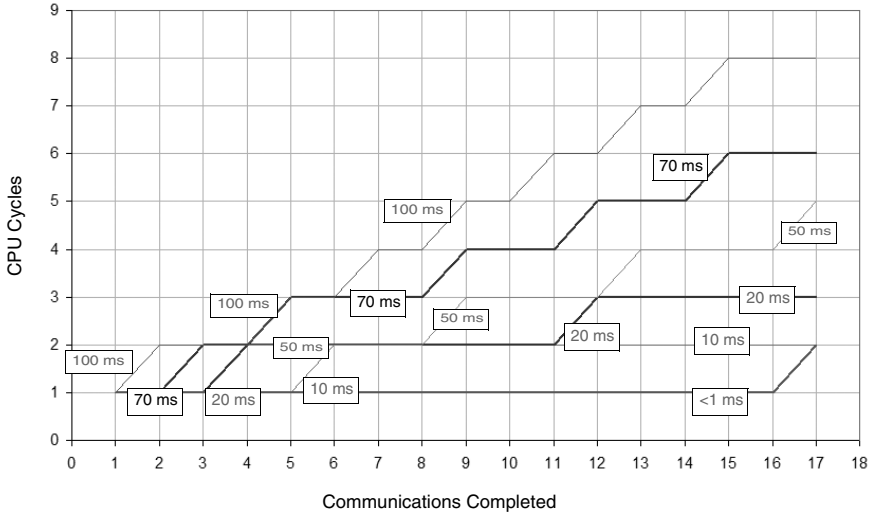
Test Setup

The following charts show Quantum PLC response times where the client request block is triggered in PLC logic by reading data from a Modbus server. The graphs represent the number of CPU cycles required for the PLC to complete all triggered Modbus client requests. In all cases, the PLC is a Quantum 140 CPU65150 with a 140 NOE77111 Ethernet communications module. The CPU logic scan times vary.

Modbus client response times are tracked with respect to six Modbus server response times:

- < 1 ms
- 10 ms
- 20 ms
- 50 ms
- 70 ms
- 100 ms

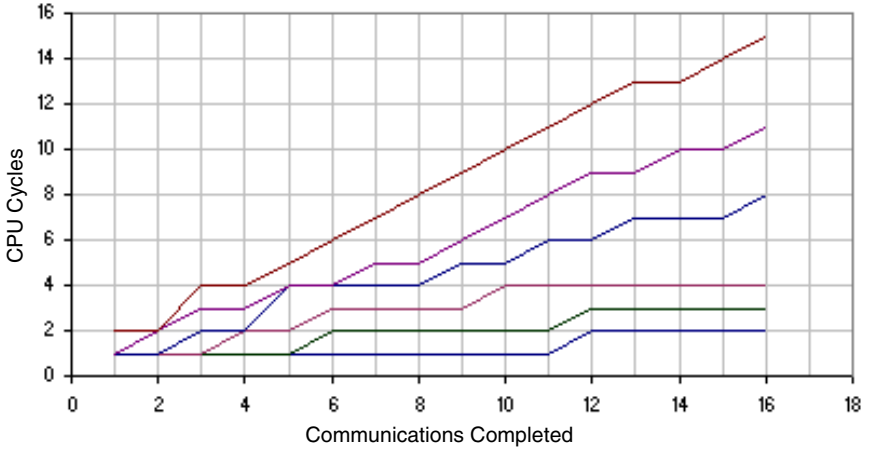
At a CPU Scan Time of 200 ms



The table below shows the data points used to generate the graph represented above.

PLC Scan (ms)	Server Response Time (ms)					
200	**<1**	**10**	**20**	**50**	**70**	**100**
Requests Sent	**PLC Cycles to Receive Response**					
1	1	1	1	1	1	1
2	1	1	1	1	1	2
3	1	1	1	2	2	2
4	1	1	2	2	2	2
5	1	1	2	2	3	3
6	1	2	2	2	3	3
7	1	2	2	2	3	4
8	1	2	2	2	3	4
9	1	2	2	3	4	5
10	1	2	2	3	4	5
11	1	2	2	3	4	6
12	1	2	3	3	5	6
13	1	2	3	4	5	7
14	1	2	3	4	5	7
15	1	2	3	4	6	8
16	1	2	3	4	6	8
17	2	2	3	5	6	8

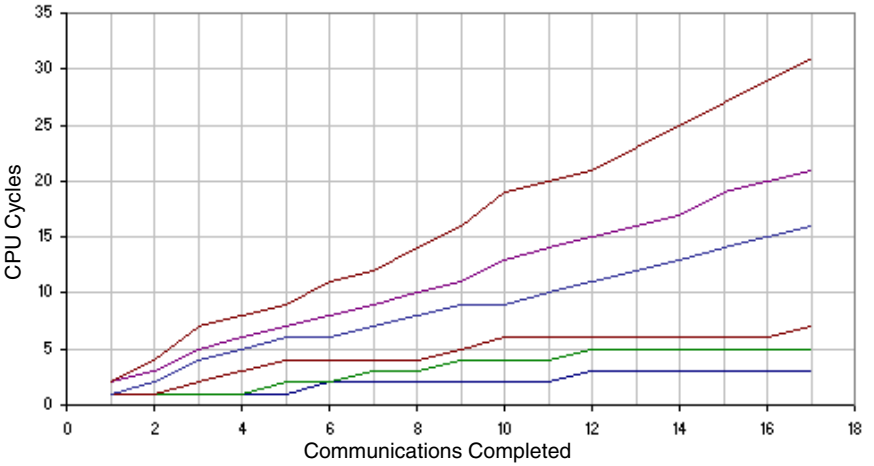
At a CPU Scan Time of 100 ms



The table below shows the data points used to generate the graph represented above.

PLC Scan (ms)	**Server Response Time (ms)**					
100	**<1**	**10**	**20**	**50**	**70**	**100**
Requests Sent	**PLC Cycles to Receive Response**					
1	1	1	1	1	1	2
2	1	1	1	1	2	2
3	1	1	1	2	3	4
4	1	1	2	4	3	4
5	1	1	2	4	4	5
6	1	2	3	4	4	6
7	1	2	3	4	5	7
8	1	2	4	4	6	8
9	1	2	4	5	6	9
10	1	2	4	5	7	10
11	2	3	4	6	8	11
12	2	3	4	6	8	12
13	2	3	4	7	9	13
14	2	3	4	7	10	13
15	2	3	4	7	10	14
16	2	3	4	8	11	15
17	2	3	4	8	12	16

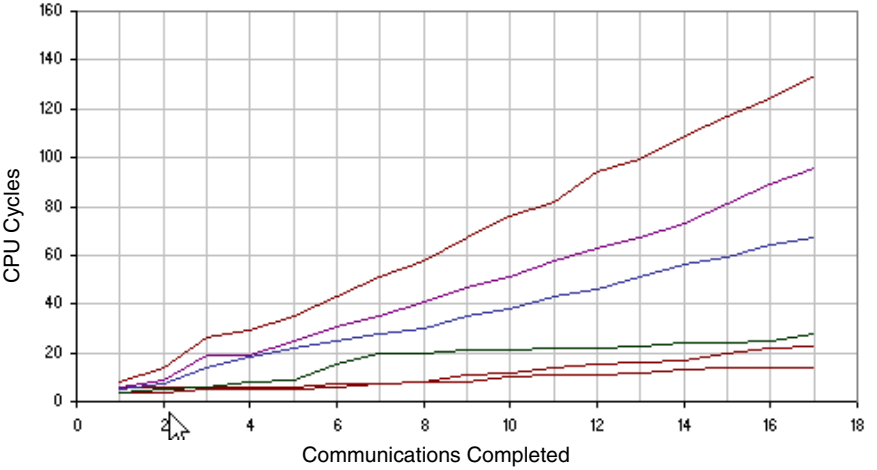
At a CPU Scan Time of 50 ms



The table below shows the data points used to generate the graph represented above.

PLC Scan (ms)	Server Response Time (ms)					
50	**<1**	**10**	**20**	**50**	**70**	**100**
Requests Sent	**PLC Cycles to Receive Response**					
1	1	1	1	1	2	2
2	1	1	1	2	3	4
3	1	1	2	4	6	7
4	2	2	3	5	6	7
5	2	2	4	5	7	9
6	2	2	4	6	8	11
7	2	3	4	7	9	13
8	2	3	5	8	10	14
9	2	3	5	8	11	16
10	2	4	6	9	13	19
11	3	4	6	10	14	20
12	3	4	6	11	15	21
13	3	5	6	12	16	23
14	3	5	6	13	18	25
15	3	5	6	14	19	27
16	3	5	6	15	20	29
17	3	5	7	16	22	31

At a CPU Scan Time of 10 ms



The table below shows the data points used to generate the graph represented above.

PLC Scan (ms)	**Server Response Time (ms)**					
10	**<1**	**10**	**20**	**50**	**70**	**100**
Requests Sent	**PLC Cycles to Receive Response**					
1	6	4	4	5	5	8
2	6	5	5	8	10	15
3	7	5	6	16	18	28
4	7	5	6	18	19	29
5	7	6	7	21	25	36
6	7	6	19	26	30	43
7	7	7	21	28	35	51
8	7	7	21	30	41	58
9	8	12	21	34	46	66
10	9	12	21	38	51	74
11	9	14	22	42	57	82
12	10	14	22	46	63	91
13	11	16	23	50	69	99
14	12	17	24	55	75	108
15	13	19	24	59	81	117
16	13	22	26	64	88	126
17	14	23	28	68	95	136

Modbus Client Response Times: Quantum 140 CPU43412A with a 140 NOE77101 Ethernet Communications Module

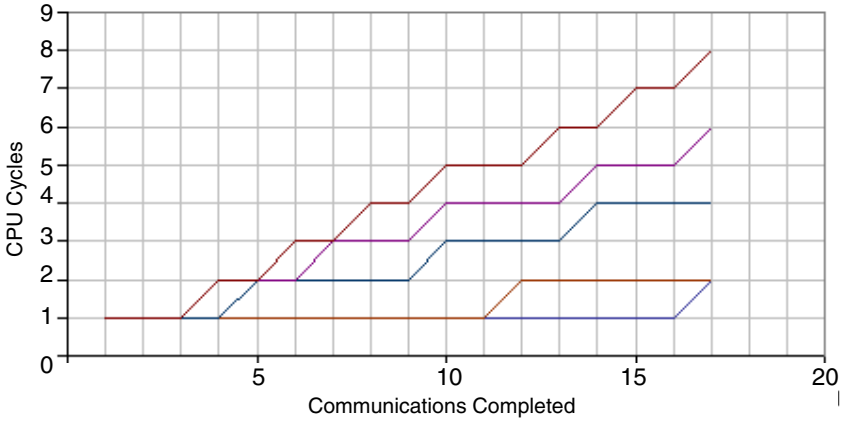
Test Setup

The following charts show Modbus client response times where the client request block is triggered in PLC logic by reading data from a Modbus server. The graphs represent the number of CPU cycles required for the PLC to complete all triggered Modbus client requests. In all cases, the PLC is a Quantum 140 CPU43412A with a 140 NOE77101 Ethernet communications module. The CPU logic scan times vary.

Modbus client response times are tracked with respect to six Modbus server response times:

- < 1 ms
- 10 ms
- 20 ms
- 50 ms
- 70 ms
- 100 ms

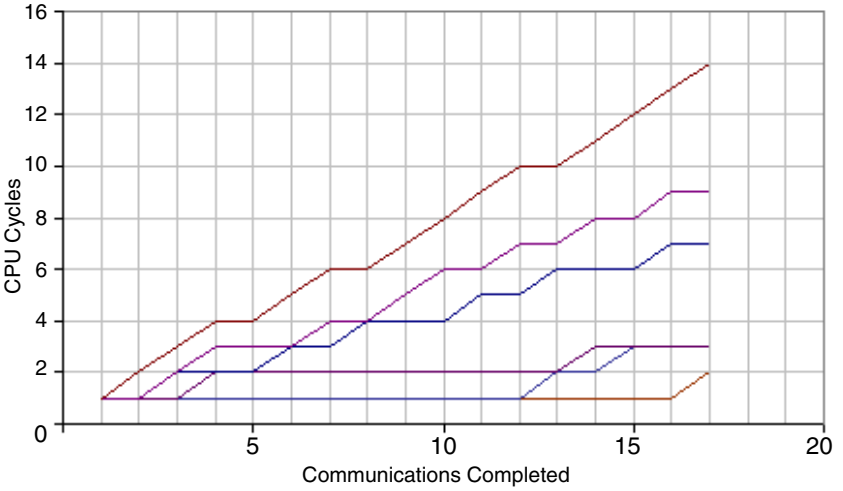
At a CPU Scan Time of 200 ms



The table below shows the data points used to generate the graph represented above.

PLC Scan (ms)	Server Response Time (ms)					
200	**<1**	**10**	**20**	**50**	**70**	**100**
Requests Sent	**PLC Cycles to Receive Response**					
1	1	1	1	1	1	1
2	1	1	1	1	1	1
3	1	1	1	1	1	1
4	1	1	1	1	2	2
5	1	1	1	2	2	2
6	1	1	1	2	2	3
7	1	1	1	2	3	3
8	1	1	1	2	3	4
9	1	1	1	2	3	4
10	1	1	1	3	4	5
11	1	1	1	3	4	5
12	1	1	2	3	4	5
13	1	1	2	3	4	6
14	1	1	2	4	5	6
15	1	1	2	4	5	7
16	1	1	2	4	5	7
17	2	2	2	4	6	8

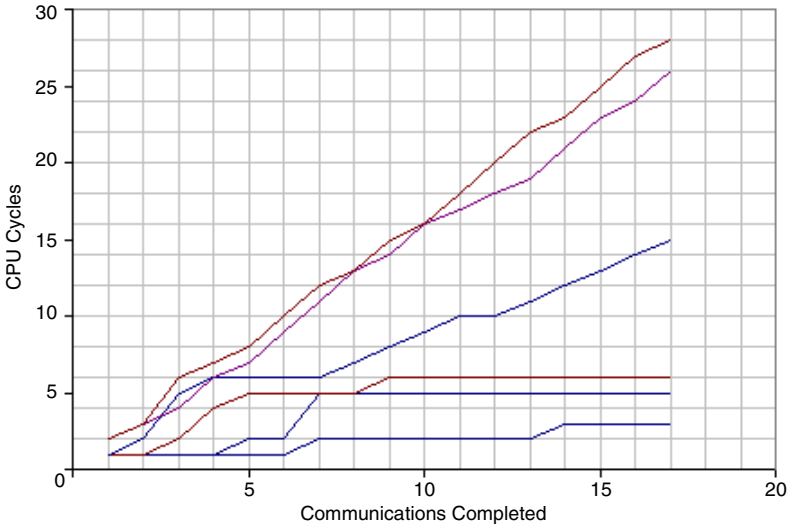
At a CPU Scan Time of 100 ms



The table below shows the data points used to generate the graph represented above.

PLC Scan (ms)	Server Response Time (ms)					
100	**<1**	**10**	**20**	**50**	**70**	**100**
Requests Sent	**PLC Cycles to Receive Response**					
1	1	1	1	1	1	1
2	1	1	1	1	1	2
3	1	1	1	2	2	3
4	1	1	2	2	3	4
5	1	1	2	2	3	4
6	1	1	2	3	3	5
7	1	1	2	3	4	6
8	1	1	2	4	4	6
9	1	1	2	4	5	7
10	1	1	2	4	6	8
11	1	1	2	5	6	9
12	1	1	2	5	7	10
13	1	2	2	6	7	10
14	1	2	3	6	8	11
15	1	3	3	6	8	12
16	1	3	3	7	9	13
17	2	3	3	7	9	14

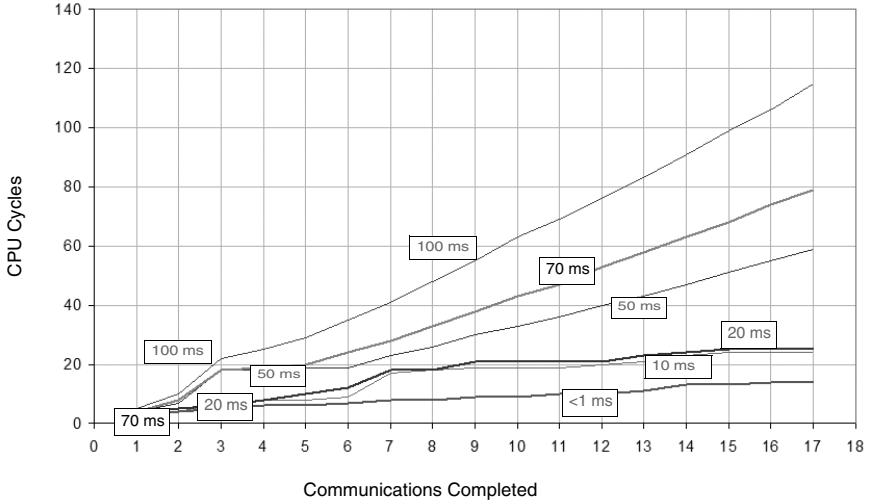
At a CPU Scan Time of 50 ms



The table below shows the data points used to generate the graph represented above.

PLC Scan (ms)	Server Response Time (ms)					
50	**<1**	**10**	**20**	**50**	**70**	**100**
Requests Sent	**PLC Cycles to Receive Response**					
1	1	1	1	1	2	2
2	1	1	1	2	3	3
3	1	1	2	5	4	6
4	1	1	4	6	6	7
5	1	2	5	6	7	8
6	1	2	5	6	9	10
7	2	5	5	6	11	12
8	2	5	5	7	13	13
9	2	5	6	8	14	15
10	2	5	6	9	16	16
11	2	5	6	10	17	18
12	2	5	6	10	18	20
13	2	5	6	11	19	22
14	3	5	6	12	21	23
15	3	5	6	13	23	25
16	3	5	6	14	24	27
17	3	5	6	15	26	28

At a CPU Scan Time of 10 ms



The table below shows the data points used to generate the graph represented above.

PLC Scan (ms)	Server Response Time (ms)					
10	**<1**	**10**	**20**	**50**	**70**	**100**
Requests Sent	**PLC Cycles to Receive Response**					
1	3	4	4	4	4	5
2	4	4	5	7	8	10
3	5	7	6	18	18	22
4	6	8	8	18	19	25
5	6	8	10	19	20	29
6	7	9	12	19	24	35
7	8	17	18	23	28	41
8	8	18	18	26	33	48
9	9	19	21	30	38	55
10	9	19	21	33	43	63
11	10	19	21	36	47	69
12	10	20	21	40	53	76
13	11	21	23	43	58	83
14	13	23	24	47	63	91
15	13	24	25	51	68	99
16	14	24	25	55	74	106
17	14	24	25	59	79	115

Modbus Client Response Times: Quantum 140 CPU43412A with a 140 NOE77111 Ethernet Communications Module

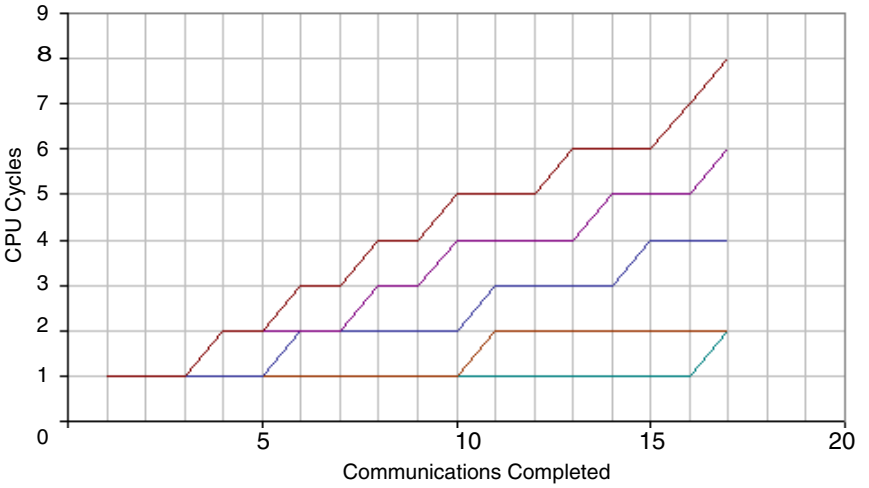
Test Setup

The following charts show Modbus client response times where the client request block is triggered in PLC logic by reading data from a Modbus server. The graphs represent the number of CPU cycles required for the PLC to complete all triggered Modbus client requests. In all cases, the PLC is a Quantum 140 CPU43412A with a 140 NOE77111 Ethernet communications module. The CPU logic scan times vary.

Modbus client response times are tracked with respect to six Modbus server response times:

- < 1 ms
- 10 ms
- 20 ms
- 50 ms
- 70 ms
- 100 ms

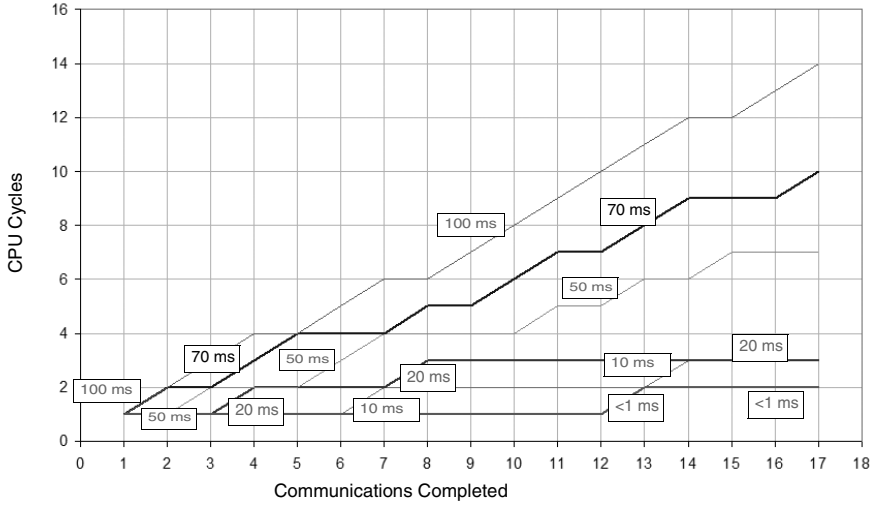
At a CPU Scan Time of 200 ms



The table below shows the data points used to generate the graph represented above.

PLC Scan (ms)	Server Response Time (ms)					
200	<1	10	20	50	70	100
Requests Sent	PLC Cycles to Receive Response					
1	1	1	1	1	1	1
2	1	1	1	1	1	1
3	1	1	1	1	1	1
4	1	1	1	1	2	2
5	1	1	1	1	2	2
6	1	1	1	2	2	3
7	1	1	1	2	2	3
8	1	1	1	2	3	4
9	1	1	1	2	3	4
10	1	1	1	2	4	5
11	1	1	2	3	4	5
12	1	1	2	3	4	5
13	1	1	2	3	4	6
14	1	1	2	3	5	6
15	1	1	2	4	5	6
16	1	1	2	4	5	7
17	2	2	2	4	6	8

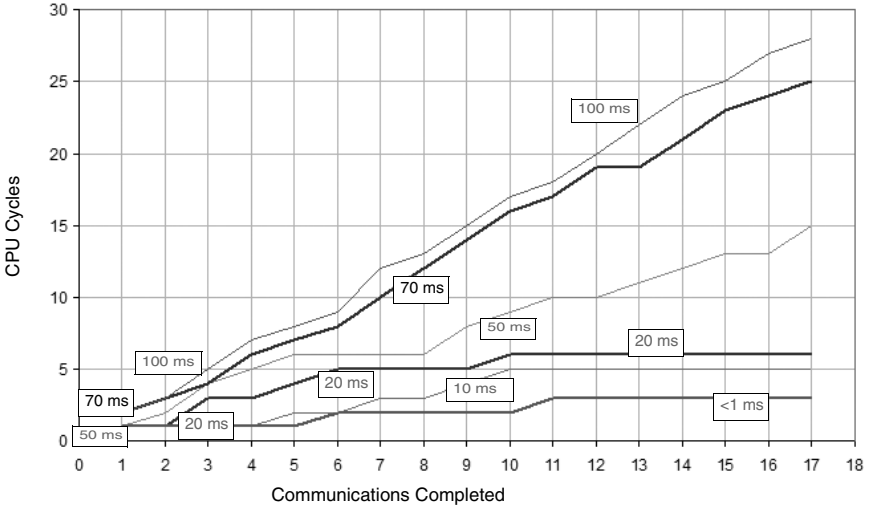
At a CPU Scan Time of 100 ms



The table below shows the data points used to generate the graph represented above.

PLC Scan (ms)	Server Response Time (ms)					
100	**<1**	**10**	**20**	**50**	**70**	**100**
Requests Sent	**PLC Cycles to Receive Response**					
1	1	1	1	1	1	1
2	1	1	1	1	1	2
3	1	1	1	1	2	3
4	1	1	1	2	2	3
5	1	1	1	2	3	4
6	1	1	2	3	3	5
7	1	1	2	3	4	6
8	1	1	2	3	4	6
9	1	1	2	4	5	7
10	1	1	2	4	6	8
11	1	1	2	4	6	9
12	1	2	2	5	7	9
13	1	2	2	6	7	10
14	1	2	2	6	8	11
15	1	3	3	6	9	12
16	1	3	3	6	9	13
17	2	3	3	7	9	14

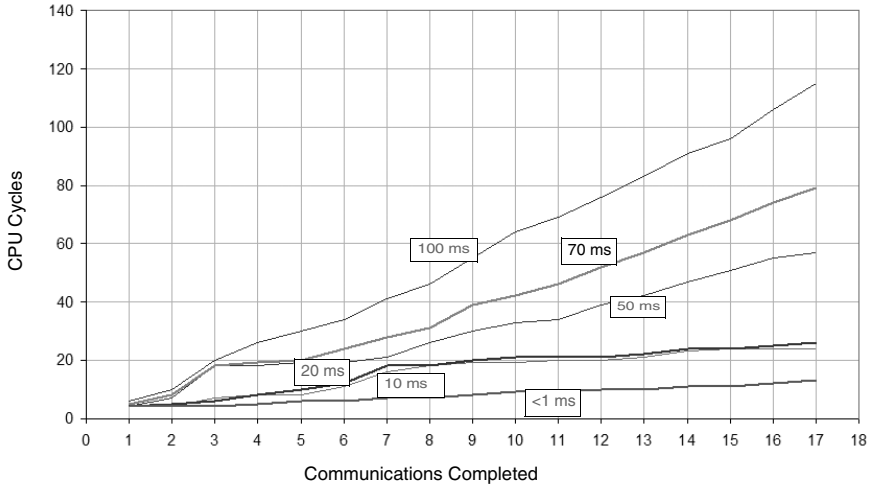
At a CPU Scan Time of 50 ms



The table below shows the data points used to generate the graph represented above.

PLC Scan (ms)	Server Response Time (ms)					
50	**<1**	**10**	**20**	**50**	**70**	**100**
Requests Sent	**PLC Cycles to Receive Response**					
1	1	1	1	1	2	2
2	1	1	1	2	3	3
3	1	1	3	4	4	5
4	1	1	3	5	6	7
5	1	2	4	6	7	8
6	2	2	5	6	8	9
7	2	3	5	6	10	12
8	2	3	5	6	12	13
9	2	4	5	8	14	15
10	2	5	6	9	16	17
11	3	5	6	10	17	18
12	3	5	6	10	19	20
13	3	5	6	11	19	22
14	3	5	6	12	21	24
15	3	5	6	13	23	25
16	3	5	6	13	24	27
17	3	5	6	15	25	28

At a CPU Scan Time of 10 ms



The table below shows the data points used to generate the graph represented above.

PLC Scan (ms)	Server Response Time (ms)					
10	**<1**	**10**	**20**	**50**	**70**	**100**
Requests Sent	**PLC Cycles to Receive Response**					
1	4	4	4	4	5	6
2	4	4	5	7	8	10
3	4	7	6	18	18	20
4	5	8	8	18	19	26
5	6	8	10	19	20	30
6	6	11	12	19	24	34
7	7	16	18	21	28	41
8	7	18	18	26	31	46
9	8	19	20	30	39	55
10	9	19	21	33	42	64
11	9	20	21	34	46	69
12	10	20	21	39	52	76
13	10	21	22	42	57	83
14	11	23	24	47	63	91
15	11	24	24	51	68	96
16	12	24	25	55	74	106
17	13	24	26	57	79	115

Gateway Response Time and Timeout Measurements

D

At a Glance

Overview

This appendix illustrates some performance measurements for devices with various response times when they communicate on a network through an EGX200, EGX400, or 174CEV30020 serial gateway. Separate measurements are given for devices that communicate successfully and for the same devices when a single request failure is experienced.

What's in this Chapter?

This chapter contains the following sections:

Section	Topic	Page
D.1	EGX200 Gateway Serial Server Response Time and Timeout Measurements	446
D.2	EGX400 Gateway Serial Server Response Time and Timeout Measurements	457
D.3	174CEV30020 Gateway Serial Server Response Time and Timeout Measurements	468

D.1 EGX200 Gateway Serial Server Response Time and Timeout Measurements

At a Glance

Overview

The performance of serial devices with response times of 50 ms, 100 ms, 200 ms, and 500 ms are measured as they communicate across a network through an EGX200 Modbus-to-Ethernet gateway. Network speeds of 9600 baud and 19 200 baud are considered. Measurements are taken for both successful communications and for situations where a single request failure is experienced followed by a successful retry.

What's in this Section?

This section contains the following topics:

Topic	Page
EGX200 Serial Server Response Times	447
EGX200 Serial Server Response Measurements with One Request Timeout	452

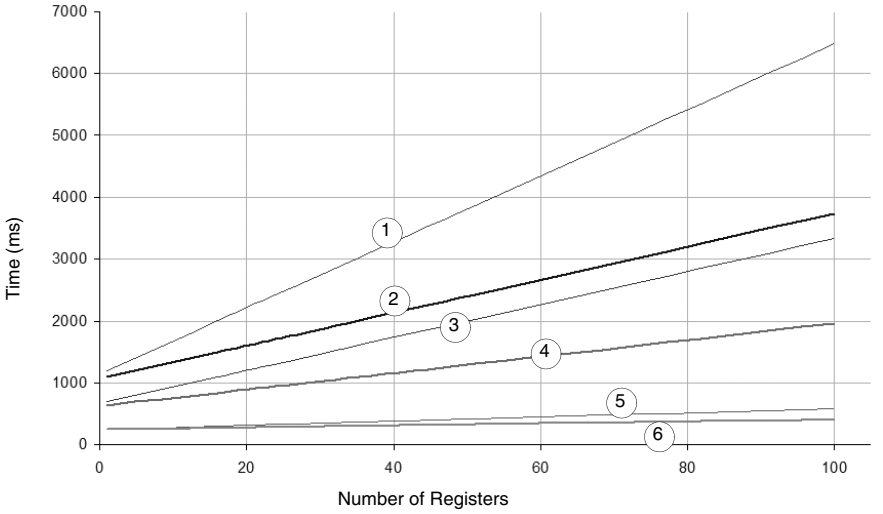
EGX200 Serial Server Response Times

Test Setup

The following charts track the time it takes to get responses from a certain number of requests sent to devices connected on the serial side of the EGX200 gateway. The performance is based on network baud rates of both 9600 and 19 200 and on the amount of data (i.e., the number of registers) requested. The following legend describes the baud rate and number of requests sent, as tracked in all four of the charts that follow:

Curve	Number of Requests	Baud Rate
1	16	9600
2		19 200
3	8	9600
4		19 200
5	1	9600
6		19 200

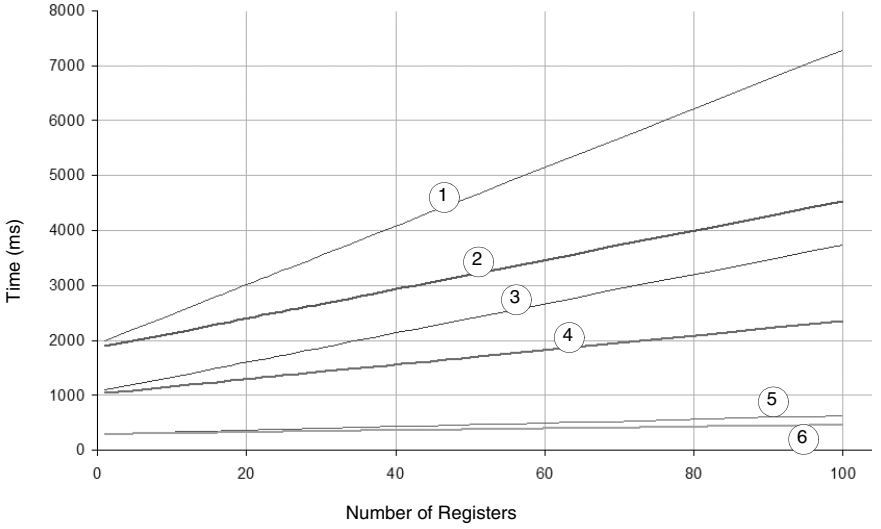
Serial Devices with 50 ms Response Time



The table below shows the data points used to generate the graph represented above.

Device	Serial Server Response TIme = 50						
EGX200	Time to Complete All Requests						
Baud Rate	9600			19200			
Number of Registers	1 Request	8 Requests	16 Requests	1 Request	8 Requests	16 Requests	Bridge Time
1	250.8333333	694.1666667	1200.833333	244.1666667	640.83333333	1094.166667	187.5
16	300.8333333	1094.166667	2000.833333	269.1666667	840.8333333	1494.166667	187.5
32	354.1666667	1520.833333	2854.166667	295.8333333	1054.1666667	1920.833333	187.5
64	460.8333333	2374.166667	4560.833333	349.1666667	1480.833333	2774.166667	187.5
100	580.8333333	3334.166667	6480.833333	409.1666667	1960.833333	3734.166667	187.5

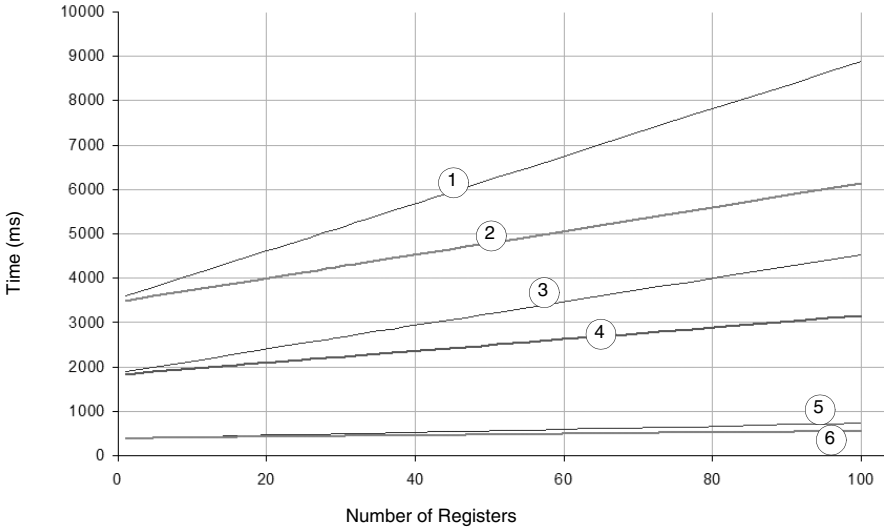
Serial Devices with 100 ms Response Time



The table below shows the data points used to generate the graph represented above.

Device	Serial Server Response TIme = 100						
EGX200	Time to Complete All Requests						
Baud Rate	9600			19200			
Number of Registers	1 Request	8 Requests	16 Requests	1 Request	8 Requests	16 Requests	Bridge Time
1	300.8333333	1094.166667	2000.833333	294.1666667	1040.833333	1894.166667	187.5
16	350.8333333	1494.166667	2800.833333	319.1666667	1240.833333	2294.166667	187.5
32	404.1666667	1920.833333	3654.166667	345.8333333	1454.166667	2720.833333	187.5
64	510.8333333	2774.166667	5360.833333	399.166667	1880.833333	3574.166667	187.5
100	630.8333333	3734.166667	7280.833333	459.166667	2360.833333	4534.166667	187.5

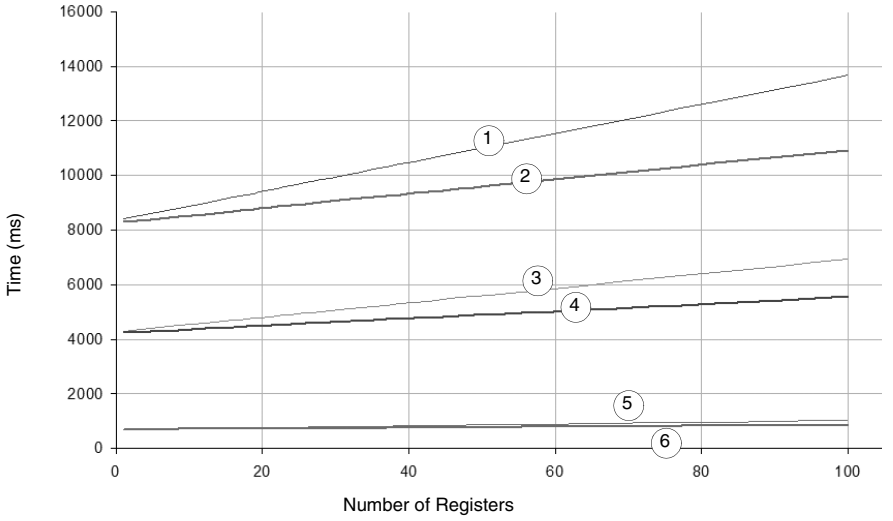
Serial Devices with 200 ms Response Time



The table below shows the data points used to generate the graph represented above.

Device	Serial Server Response TIme = 200						
EGX200	Time to Complete All Requests						
Baud Rate	9600			19200			
Number of Registers	1 Request	8 Requests	16 Requests	1 Request	8 Requests	16 Requests	Bridge Time
1	400.8333333	1894.166667	3600.833333	394.1666667	1840.833333	3494.166667	187.5
16	450.8333333	2294.166667	4400.833333	419.1666667	2040.833333	3894.166667	187.5
32	504.1666667	2720.833333	5254.166667	445.8333333	2254.166667	4320.833333	187.5
64	610.8333333	3574.166667	6960.833333	499.1666667	2680.833333	5174.166667	187.5
100	730.8333333	4534.166667	8880.833333	559.1666667	3160.833333	6134.166667	187.5

Serial Devices with 500 ms Response Time



The table below shows the data points used to generate the graph represented above.

Device	Serial Server Response TIme = 500						
EGX200	Time to Complete All Requests						
Baud Rate	9600			19200			
Number of Registers	1 Request	8 Requests	16 Requests	1 Request	8 Requests	16 Requests	Bridge Time
1	700.8333333	4294.16667	8400.833333	694.1666667	4240.833333	8294.166667	187.5
16	750.8333333	4694.16667	9200.833333	719.1666667	4440.833333	8694.166667	187.5
32	804.1666667	5120.83333	10054.16667	745.8333333	4654.166667	9120.833333	187.5
64	910.8333333	5974.16667	11760.83333	799.1666667	5080.833333	9974.166667	187.5
100	1030.833333	6934.16667	13680.83333	859.1666667	5560.833333	10934.16667	187.5

EGX200 Serial Server Response Measurements with One Request Timeout

Test Setup

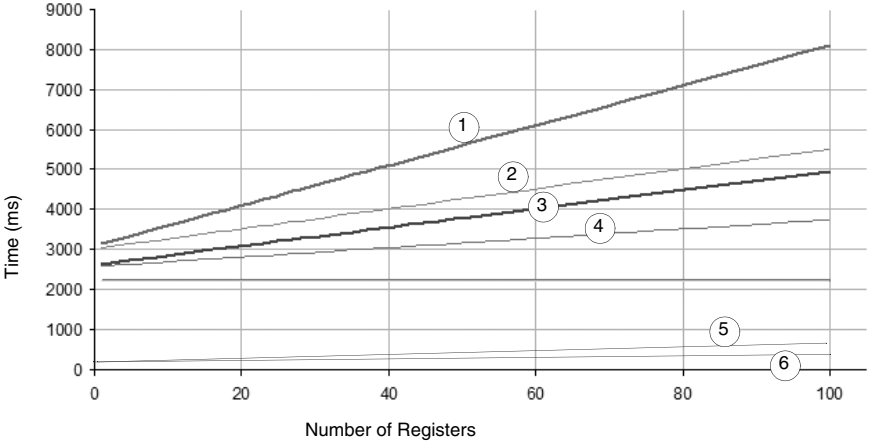
The following charts show the time it takes to get responses from a certain number of requests sent to devices connected on the serial side of the EGX200 gateway when the system experiences a failure of one communications request (e.g., a disconnected serial device). The failure results in a 1000 ms timeout of the initial request followed by one retry of the request.

Note: One request failure increases the response times for all requests.

The performance is based on network baud rates of both 9600 and 19 200 and on the amount of data (i.e., the number of registers) requested. The following legend describes the baud rate and number of requests sent, as tracked in all four of the charts that follow:

Curve	Number of Requests	Baud Rate
1	16	9600
2		19 200
3	8	9600
4		19 200
5	1	9600
6		19 200

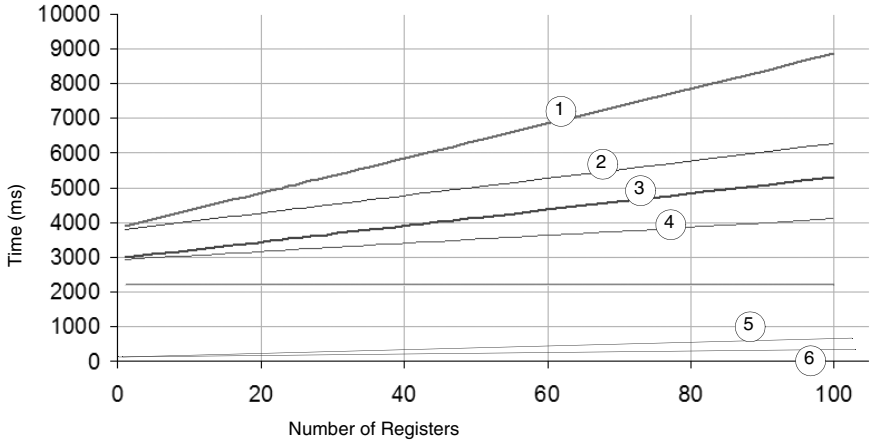
Serial Devices with 50 ms Response Time



The table below shows the data points used to generate the graph represented above.

Device	**Serial Server Response TIme = 50**						**Timeout 1000 ms 1 Retry**
EGX200	**Time to Complete All Requests**						
Baud Rate	**9600**			**19200**			
Number of Registers	**1 Request**	**8 Requests**	**16 Requests**	**1 Request**	**8 Requests**	**16 Requests**	**Bridge Time**
1	2200.83	2644.163333	3150.83	2194.17	2590.836667	3044.17	187.5
16	2200.83	2994.163333	3900.83	2194.17	2765.836667	3419.17	187.5
32	2200.83	3367.496667	4700.83	2194.17	2952.50333	3819.17	187.5
64	2200.83	4114.163333	6300.83	2194.17	3325.836667	4619.17	187.5
100	2200.83	4954.163333	8100.83	2194.17	3745.83667	5519.17	187.5

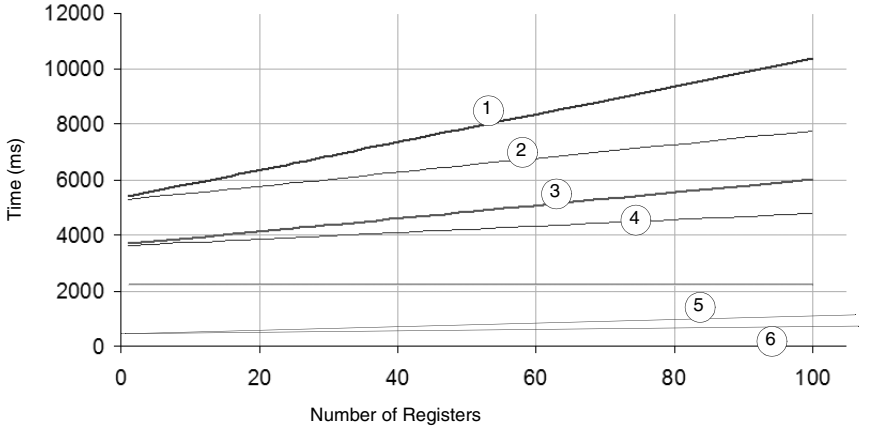
Serial Devices with 100 ms Response Time



The table below shows the data points used to generate the graph represented above.

Device	**Serial Server Response TIme = 100**						**Timeout 1000 ms 1 Retry**
EGX200	**Time to Complete All Requests**						
Baud Rate	**9600**			**19200**			
Number of Registers	**1 Request**	**8 Requests**	**16 Requests**	**1 Request**	**8 Requests**	**16 Requests**	**Bridge Time**
1	2200.83	2994.163333	3900.83	2194.17	2940.836667	3794.17	187.5
16	2200.83	3344.163333	4650.83	2194.17	3115.836667	4169.17	187.5
32	2200.83	3717.496667	5450.83	2194.17	3302.50333	4569.17	187.5
64	2200.83	4464.163333	7050.83	2194.17	3675.836667	5369.17	187.5
100	2200.83	5304.163333	8850.83	2194.17	4095.836667	6269.17	187.5

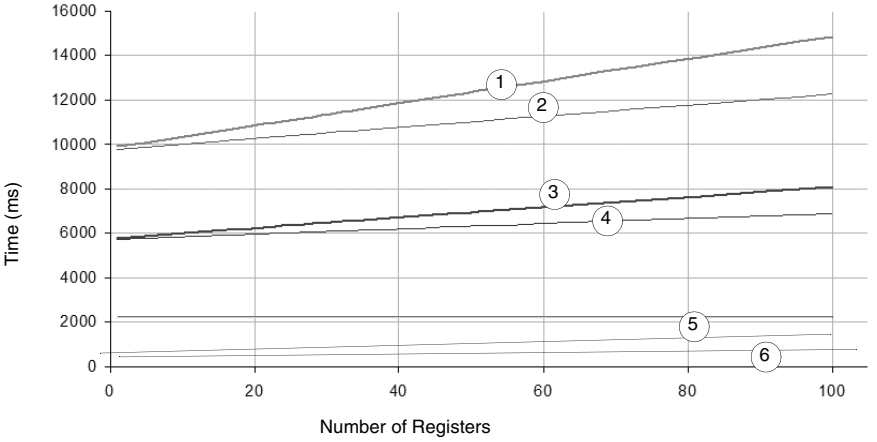
Serial Devices with 200 ms Response Time



The table below shows the data points used to generate the graph represented above.

Device	Serial Server Response TIme = 200						Timeout 1000 ms 1 Retry
EGX200	Time to Complete All Requests						
Baud Rate	9600			19200			
Number of Registers	1 Request	8 Requests	16 Requests	1 Request	8 Requests	16 Requests	Bridge Time
1	2200.83	3694.163333	5400.83	2194.17	3640.836667	5294.17	187.5
16	2200.83	4044.163333	6150.83	2194.17	3815.836667	5669.17	187.5
32	2200.83	4417.496667	6950.83	2194.17	4002.50333	6069.17	187.5
64	2200.83	5164.163333	8550.83	2194.17	4375.836667	6869.17	187.5
100	2200.83	6004.163333	10350.83	2194.17	4795.83667	7769.17	187.5

Serial Devices with 500 ms Response Time



The table below shows the data points used to generate the graph represented above.

Device	Serial Server Response TIme = 500						Timeout 1000 ms 1 Retry
EGX200	Time to Complete All Requests						
Baud Rate	9600			19200			
Number of Registers	1 Request	8 Requests	16 Requests	1 Request	8 Requests	16 Requests	Bridge Time
1	2200.83	5794.163333	9900.83	2194.17	5740.836667	9794.17	187.5
16	2200.83	6114.163333	10650.83	2194.17	5915.836667	10169.17	187.5
32	2200.83	6517.496667	11450.83	2194.17	6102.50333	10569.17	187.5
64	2200.83	7264.163333	13050.83	2194.17	6475.836667	11369.17	187.5
100	2200.83	8104.163333	14850.83	2194.17	6895.83667	12269.17	187.5

D.2 EGX400 Gateway Serial Server Response Time and Timeout Measurements

At a Glance

Overview

The performance of serial devices with response times of 50 ms, 100 ms, 200 ms, and 500 ms are measured as they communicate across a network through an EGX400 Modbus-to-Ethernet gateway. Network speeds of 9600 baud and 19 200 baud are considered. Measurements are taken for both successful communications and for situations where a single request failure is experienced followed by a successful retry.

What's in this Section?

This section contains the following topics:

Topic	Page
EGX400 Gateway Serial Server Response Times	458
EGX400 Serial Server Response Measurements with One Request Timeout	463

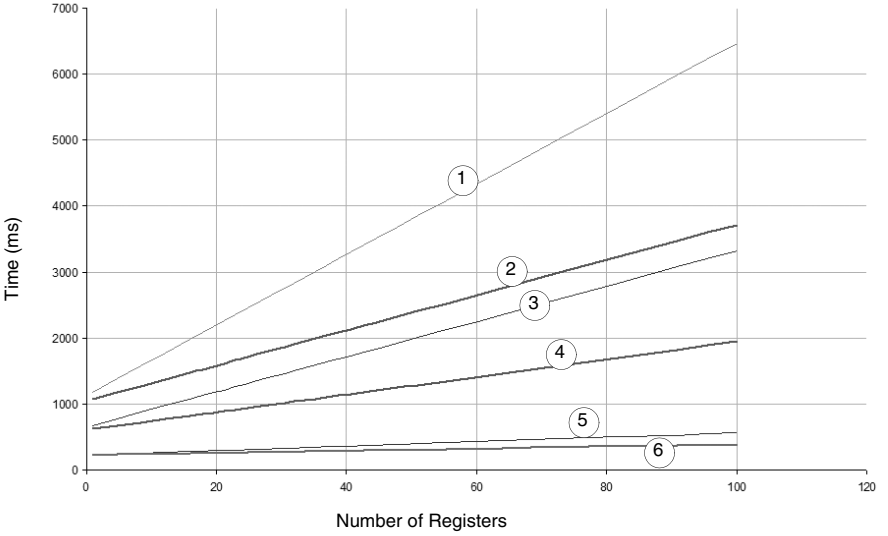
EGX400 Gateway Serial Server Response Times

Test Setup

The following charts track the time it takes to get responses from a certain number of requests sent to devices connected on the serial side of the EGX400 gateway. The performance is based on network baud rates of both 9600 and 19 200 and on the amount of data (i.e., the number of registers) requested. The following legend describes the baud rate and number of requests sent, as tracked in all four of the charts that follow:

Curve	Number of Requests	Baud Rate
1	16	9600
2		19 200
3	8	9600
4		19 200
5	1	9600
6		19 200

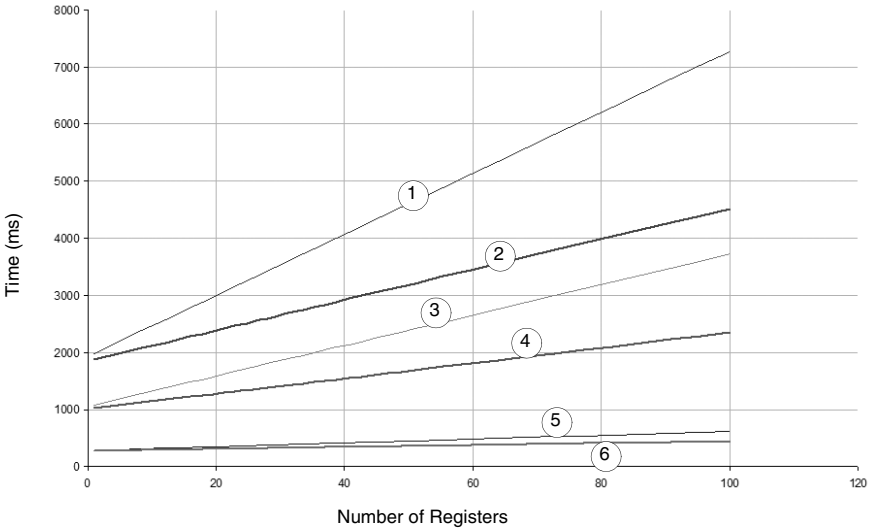
Serial Devices with 50 ms Response Time



The table below shows the data points used to generate the graph represented above.

Device	**Serial Server Response TIme = 50**						
EGX200	**Time to Complete All Requests**						
Baud Rate	**9600**			**19200**			
Number of Registers	**1 Request**	**8 Requests**	**16 Requests**	**1 Request**	**8 Requests**	**16 Requests**	**Bridge Time**
1	235.3333333	678.6666667	1185.333333	228.6666667	625.33333333	1078.666667	172
16	285.3333333	1078.666667	1985.333333	253.6666667	825.3333333	1478.666667	172
32	338.6666667	1505.333333	2838.666667	280.3333333	1038.6666667	1905.333333	172
64	445.3333333	2358.666667	4545.333333	333.6666667	1465.333333	2758.666667	172
100	565.3333333	3318.666667	6465.333333	393.6666667	1945.333333	3718.666667	172

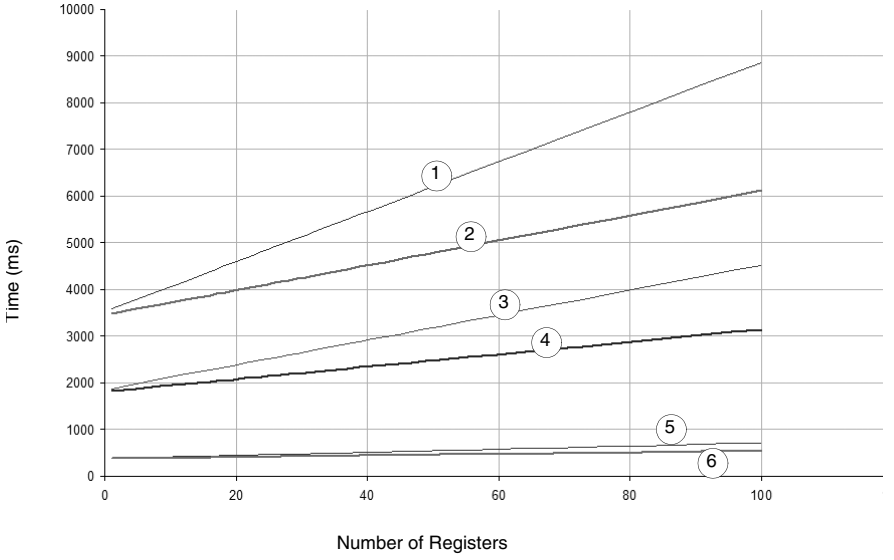
Serial Devices with 100 ms Response Time



The table below shows the data points used to generate the graph represented above.

Device	**Serial Server Response TIme = 100**						
EGX200	**Time to Complete All Requests**						
Baud Rate	**9600**			**19200**			
Number of Registers	**1 Request**	**8 Requests**	**16 Requests**	**1 Request**	**8 Requests**	**16 Requests**	**Bridge Time**
1	285.3333333	1078.666667	1985.333333	278.6666667	1025.3333333	1878.666667	172
16	335.3333333	1478.666667	2785.333333	303.6666667	1225.3333333	2278.666667	172
32	388.6666667	1905.333333	3638.666667	330.3333333	1438.6666667	2705.333333	172
64	495.3333333	2758.666667	5345.333333	383.6666667	1865.333333	3558.666667	172
100	615.3333333	3718.666667	7265.333333	443.6666667	2345.333333	4518.666667	172

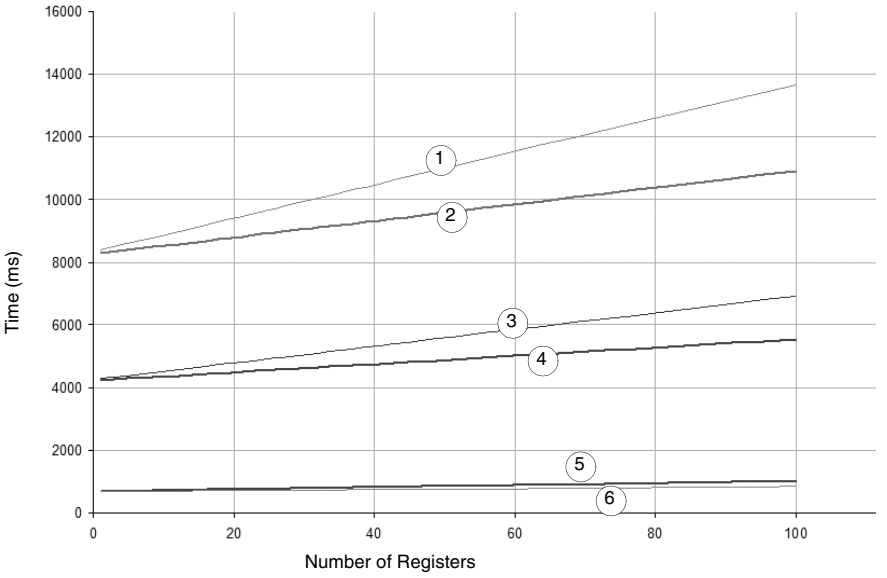
Serial Devices with 200 ms Response Time



The table below shows the data points used to generate the graph represented above.

Device	Serial Server Response TIme = 200						
EGX200	Time to Complete All Requests						
Baud Rate	9600			19200			
Number of Registers	1 Request	8 Requests	16 Requests	1 Request	8 Requests	16 Requests	Bridge Time
1	385.3333333	1878.666667	3585.333333	378.666667	1825.3333333	3478.666667	172
16	435.3333333	2278.666667	4385.333333	403.666667	2025.3333333	3878.666667	172
32	488.6666667	2705.333333	5238.666667	430.333333	2238.6666667	4305.333333	172
64	595.3333333	3558.666667	6945.333333	483.666667	2665.3333333	5158.666667	172
100	715.3333333	4518.666667	8865.333333	543.666667	3145.3333333	6118.666667	172

Serial Devices with 500 ms Response Time



The table below shows the data points used to generate the graph represented above.

Device	Serial Server Response TIme = 500						
EGX200	Time to Complete All Requests						
Baud Rate	9600			19200			
Number of Registers	1 Request	8 Requests	16 Requests	1 Request	8 Requests	16 Requests	Bridge Time
1	685.3333333	4278.666667	8385.333333	678.6666667	4225.333333	8278.666667	172
16	735.3333333	4678.666667	9185.333333	703.6666667	4425.333333	8678.666667	172
32	788.6666667	5105.333333	10038.66667	730.3333333	4638.666667	9105.333333	172
64	895.3333333	5958.666667	11745.33333	783.6666667	5065.333333	9958.666667	172
100	1015.333333	6918.666667	13665.33333	843.6666667	5545.333333	10918.66667	172

EGX400 Serial Server Response Measurements with One Request Timeout

Test Setup

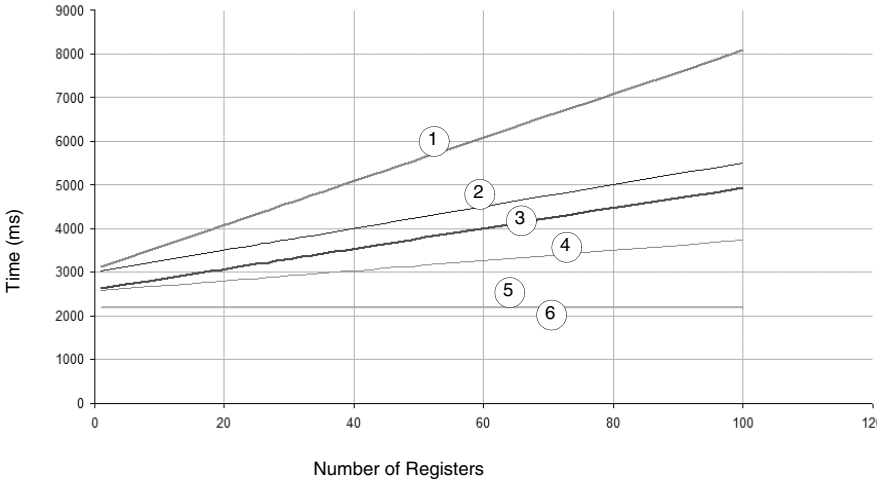
The following charts show the time it takes to get responses from a certain number of requests sent to devices connected on the serial side of the EGX400 gateway when the system experiences a failure of one communications request (e.g., a disconnected serial device). The failure results in a 1000 ms timeout of the initial request followed by one retry of the request.

Note: One request failure increases the response times for all requests.

The performance is based on network baud rates of both 9600 and 19 200 and on the amount of data (i.e., the number of registers) requested. The following legend describes the baud rate and number of requests sent, as tracked in all four of the charts that follow:

Curve	Number of Requests	Baud Rate
1	16	9600
2		19 200
3	8	9600
4		19 200
5	1	9600
6		19 200

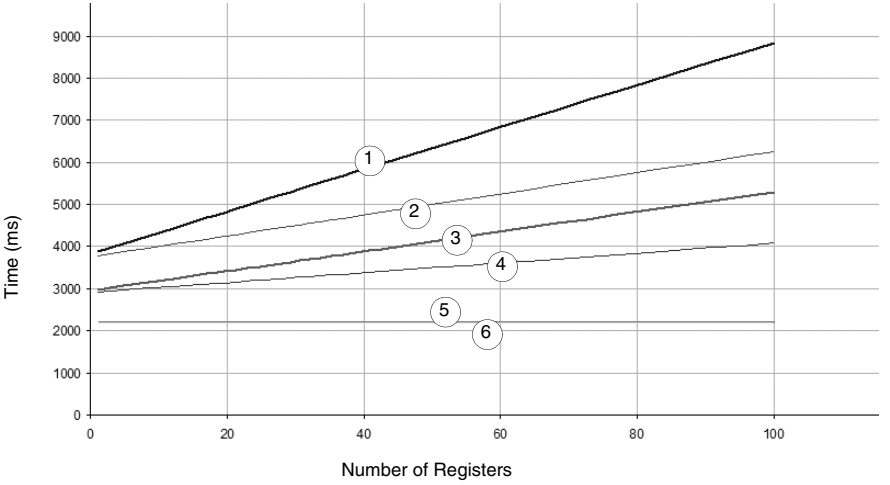
Serial Devices with 50 ms Response Time



The table below shows the data points used to generate the graph represented above.

Device	Serial Server Response TIme = 50						Timeout 1000 ms 1 Retry
EGX400	Time to Complete All Requests						
Baud Rate	9600			19200			
Number of Registers	1 Request	8 Requests	16 Requests	1 Request	8 Requests	16 Requests	Bridge Time
1	2185.33	2628.663333	3135.33	2178.67	2575.336667	3028.167	172
16	2185.33	2978.663333	3885.33	2178.67	2750.336667	3403.167	172
32	2185.33	3351.996667	4685.33	2178.67	2937.003333	3803.67	172
64	2185.33	4098.663333	6285.33	2178.67	3310.336667	4603.67	172
100	2185.33	4938.663333	8085.33	2178.67	3730.336667	5503.67	172

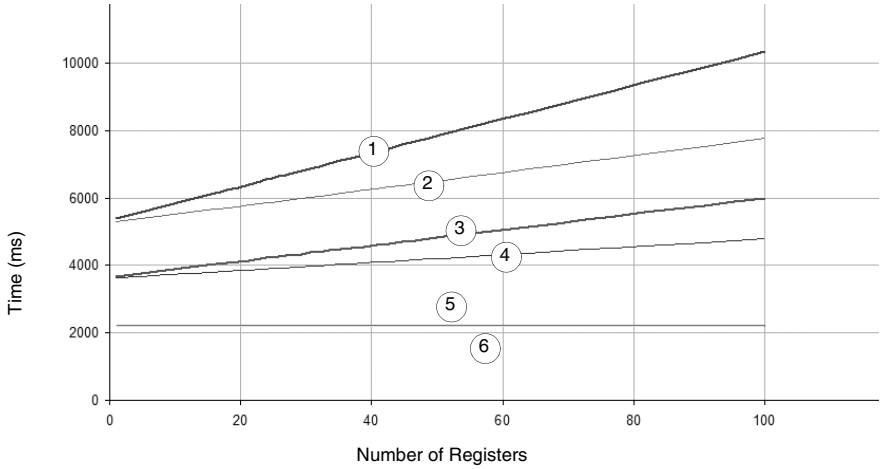
Serial Devices with 100 ms Response Time



The table below shows the data points used to generate the graph represented above.

Device	**Serial Server Response TIme = 100**						**Timeout 1000 ms 1 Retry**
EGX400	**Time to Complete All Requests**						
Baud Rate	**9600**			**19200**			
Number of Registers	**1 Request**	**8 Requests**	**16 Requests**	**1 Request**	**8 Requests**	**16 Requests**	**Bridge Time**
1	2185.33	2978.663333	3885.33	2178.67	2925.336667	3778.67	172
16	2185.33	3328.663333	4635.33	2178.67	3100.336667	4153.67	172
32	2185.33	3701.996667	5435.33	2178.67	3287.003333	4553.67	172
64	2185.33	4448.663333	7035.33	2178.67	3660.336667	5353.67	172
100	2185.33	5288.663333	8835.33	2178.67	4080.336667	6253.67	172

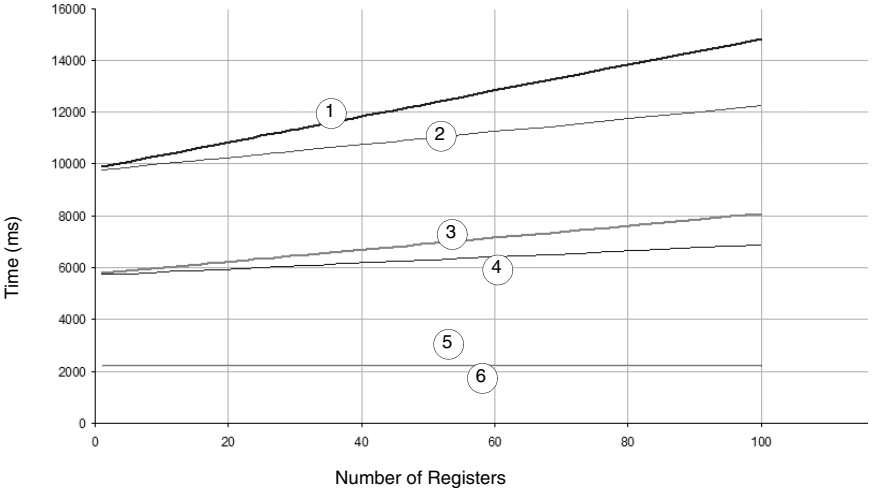
Serial Devices with 200 ms Response Time



The table below shows the data points used to generate the graph represented above.

Device	Serial Server Response TIme = 200						Timeout 1000 ms 1 Retry
EGX400	Time to Complete All Requests						
Baud Rate	9600			19200			
Number of Registers	1 Request	8 Requests	16 Requests	1 Request	8 Requests	16 Requests	Bridge Time
1	2185.33	3678.663333	5385.33	2178.67	3625.336667	5278.67	172
16	2185.33	4028.663333	6135.33	2178.67	3800.336667	5653.67	172
32	2185.33	4401.996667	6935.33	2178.67	3987.003333	6053.67	172
64	2185.33	5148.663333	8535.33	2178.67	4360.336667	6853.67	172
100	2185.33	5988.663333	10335.33	2178.67	4780.336667	7753.67	172

Serial Devices with 500 ms Response Time



The table below shows the data points used to generate the graph represented above.

Device	Serial Server Response TIme = 500						Timeout 1000 ms 1 Retry
EGX400	Time to Complete All Requests						
Baud Rate	9600			19200			
Number of Registers	1 Request	8 Requests	16 Requests	1 Request	8 Requests	16 Requests	Bridge Time
1	2185.33	5778.663333	9885.33	2178.67	5725.336667	9778.67	172
16	2185.33	6128.663333	10635.33	2178.67	5900.336667	10153.67	172
32	2185.33	6501.996667	11435.33	2178.67	6087.003333	10553.67	172
64	2185.33	7248.663333	13035.33	2178.67	6460.336667	11353.67	172
100	2185.33	8088.663333	14835.33	2178.67	6880.336667	12253.67	172

D.3 174CEV30020 Gateway Serial Server Response Time and Timeout Measurements

At a Glance

Overview

The performance of serial devices with response times of 50 ms, 100 ms, 200 ms, and 500 ms are measured as they communicate across a network through a 174CEV30020 Modbus-to-Ethernet gateway. Network speeds of 9600 baud and 19 200 baud are considered. Measurements are taken for both successful communications and for situations where a single request failure is experienced followed by a successful retry.

What's in this Section?

This section contains the following topics:

Topic	Page
174CEV30020 Gateway Serial Server Response Times	469
174CEV30020 Serial Server Response Measurements with One Request Timeout	474

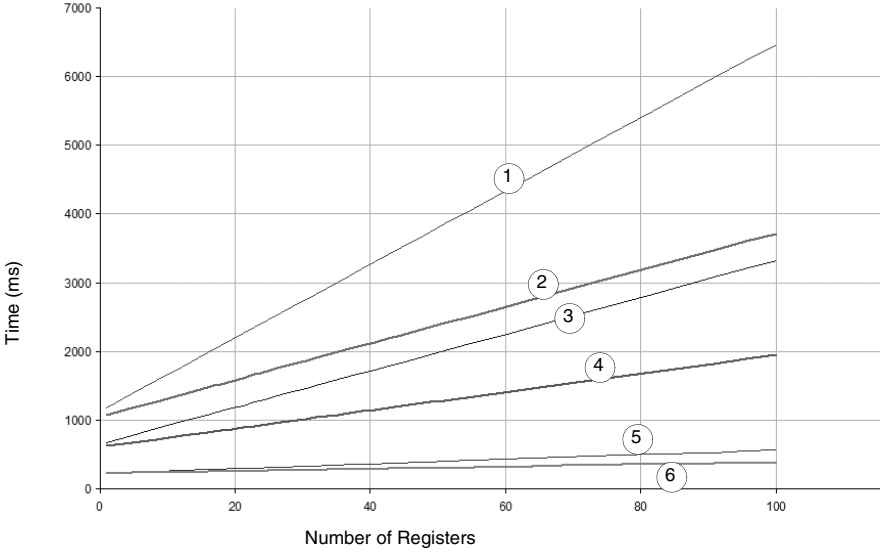
174CEV30020 Gateway Serial Server Response Times

Test Setup

The following charts track the time it takes to get responses from a certain number of requests sent to devices connected on the serial side of the 174CEV30020 gateway. The performance is based on network baud rates of both 9600 and 19 200 and on the amount of data (i.e., the number of registers) requested. The following legend describes the baud rate and number of requests sent, as tracked in all four of the charts that follow:

Curve	Number of Requests	Baud Rate
1	16	9600
2		19 200
3	8	9600
4		19 200
5	1	9600
6		19 200

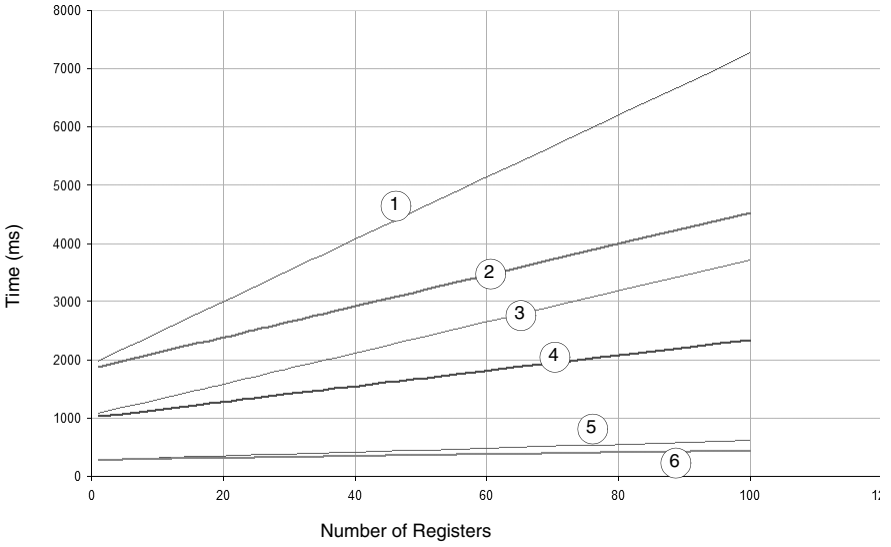
Serial Devices with 50 ms Response Time



The table below shows the data points used to generate the graph represented above.

Device	**Serial Server Response TIme = 50**						
CEV300200	**Time to Complete All Requests**						
Baud Rate	**9600**			**19200**			
Number of Registers	**1 Request**	**8 Requests**	**16 Requests**	**1 Request**	**8 Requests**	**16 Requests**	**Bridge Time**
1	201.3333333	644.6666667	1151.833333	194.6666667	591.8333333	1044.166667	138
16	251.3333333	1044.666667	1951.833333	219.6666667	791.8333333	1444.166667	138
32	304.6666667	1471.333333	2804.166667	246.3333333	1004.166667	1871.833333	138
64	411.3333333	2324.666667	4511.833333	299.6666667	1431.833333	2724.166667	138
100	531.3333333	3284.666667	6431.833333	359.6666667	1911.833333	3684.166667	138

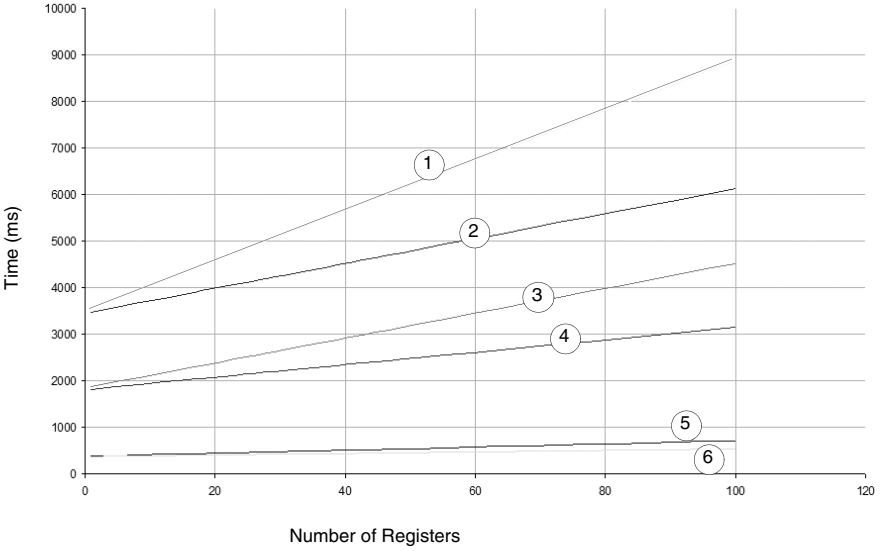
Serial Devices with 100 ms Response Time



The table below shows the data points used to generate the graph represented above.

Device	**Serial Server Response TIme = 100**						
CEV300200	**Time to Complete All Requests**						
Baud Rate	**9600**			**19200**			
Number of Registers	**1 Request**	**8 Requests**	**16 Requests**	**1 Request**	**8 Requests**	**16 Requests**	**Bridge Time**
1	251.33333	1044.66667	1951.333333	244.66667	991.333333	1844.666667	138
16	301.33333	1444.6667	2751.333333	269.66667	1191.33333	2244.666667	138
32	354.66667	1871.33333	3604.666667	296.33333	1404.66667	2671.333333	138
64	461.33333	2724.66667	5311.333333	349.66667	1831.33333	3524.666667	138
100	581.33333	3684.66667	7231.333333	409.66667	2311.33333	4484.666667	138

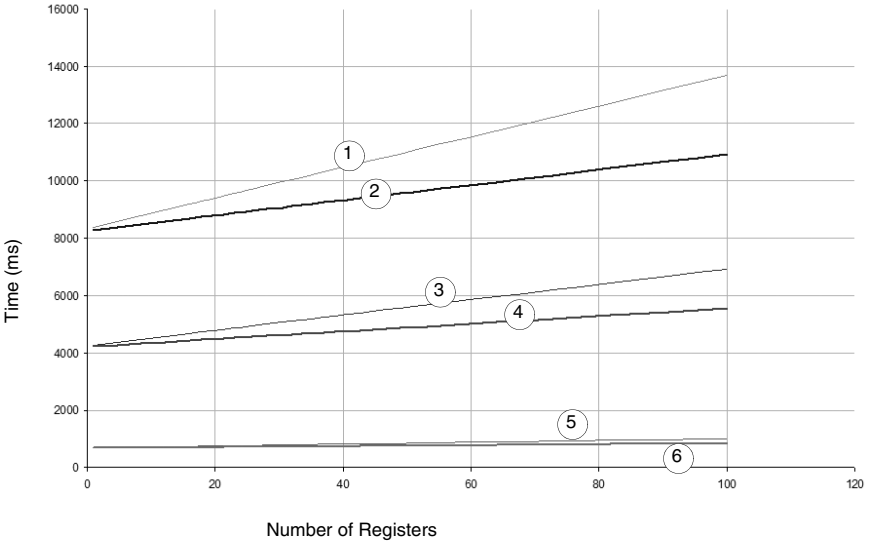
Serial Devices with 200 ms Response Time



The table below shows the data points used to generate the graph represented above.

Device	Serial Server Response TIme = 200						
CEV300200	Time to Complete All Requests						
Baud Rate	9600			19200			
Number of Registers	1 Request	8 Requests	16 Requests	1 Request	8 Requests	16 Requests	Bridge Time
1	351.33333	1844.66667	3551.333333	344.66667	1791.333333	3444.666667	138
16	401.33333	2244.66667	4351.333333	369.66667	1991.33333	3844.666667	138
32	454.66667	2671.33333	5204.666667	396.33333	2204.66667	4271.333333	138
64	561.33333	3524.66667	6911.333333	449.66667	2631.33333	5124.666667	138
100	681.33333	4484.66667	8831.333333	509.66667	3111.33333	6084.666667	138

Serial Devices with 500 ms Response Time



The table below shows the data points used to generate the graph represented above.

Device	**Serial Server Response TIme = 500**						
CEV300200	**Time to Complete All Requests**						
Baud Rate	**9600**			**19200**			
Number of Registers	**1 Request**	**8 Requests**	**16 Requests**	**1 Request**	**8 Requests**	**16 Requests**	**Bridge Time**
1	651.33333	4244.66667	8351.333333	644.66667	4191.333333	8244.666667	138
16	701.33333	4644.66667	9151.333333	669.66667	4391.33333	8644.666667	138
32	754.66667	5071.33333	10004.66667	696.33333	4604.66667	9071.333333	138
64	861.33333	5924.66667	11711.33333	749.66667	5031.33333	9924.666667	138
100	981.33333	6884.66667	13631.33333	809.66667	5511.33333	10884.66667	138

174CEV30020 Serial Server Response Measurements with One Request Timeout

Test Setup

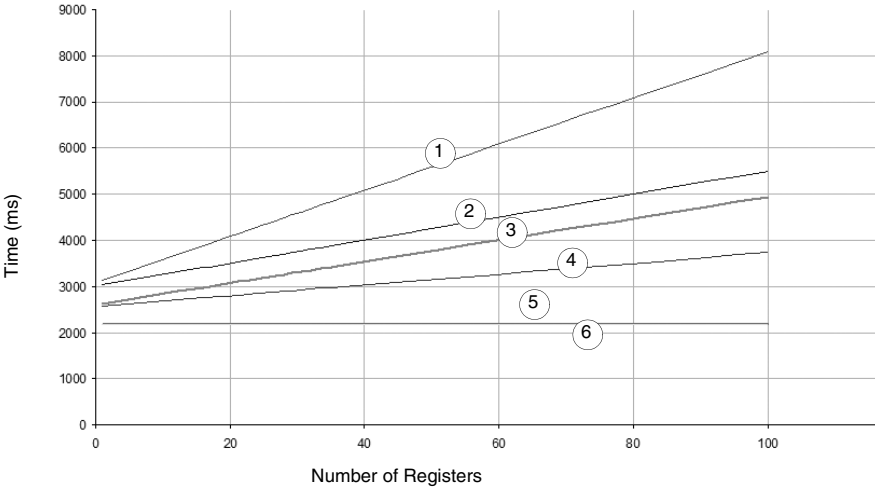
The following charts show the time it takes to get responses from a certain number of requests sent to devices connected on the serial side of the 174CEV30020 gateway when the system experiences a failure of one communications request (e.g., a disconnected serial device). The failure results in a 1000 ms timeout of the initial request followed by one retry of the request.

Note: One request failure increases the response times for all requests.

The performance is based on network baud rates of both 9600 and 19 200 and on the amount of data (i.e., the number of registers) requested. The following legend describes the baud rate and number of requests sent, as tracked in all four of the charts that follow:

Curve	Number of Requests	Baud Rate
1	16	9600
2		19 200
3	8	9600
4		19 200
5	1	9600
6		19 200

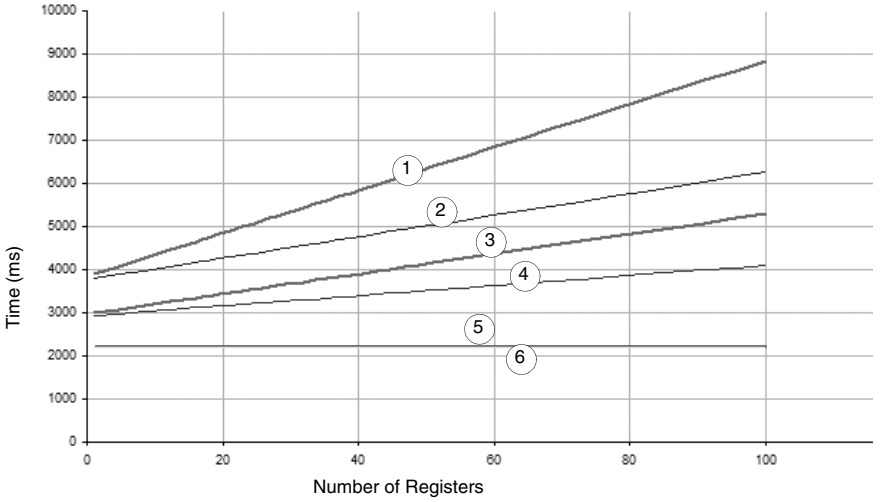
Serial Devices with 50 ms Response Time



The table below shows the data points used to generate the graph represented above.

Device	Serial Server Response TIme = 50						
CEV30020	Time to Complete All Requests						
Baud Rate	9600			19200			
Number of Registers	1 Request	8 Requests	16 Requests	1 Request	8 Requests	16 Requests	Bridge Time
1	2151.33	2594.663333	3101.33	2144.67	2541.336667	2994.67	138
16	2151.33	2944.663333	3851.33	2144.67	2716.336667	3369.167	138
32	2151.33	3317.333333	4651.33	2144.67	2903.166667	3769.67	138
64	2151.33	4064.996667	6251.33	2144.67	3276.336667	4569.67	138
100	2151.33	4904.663333	8051.33	2144.67	3696.336667	5469.67	138

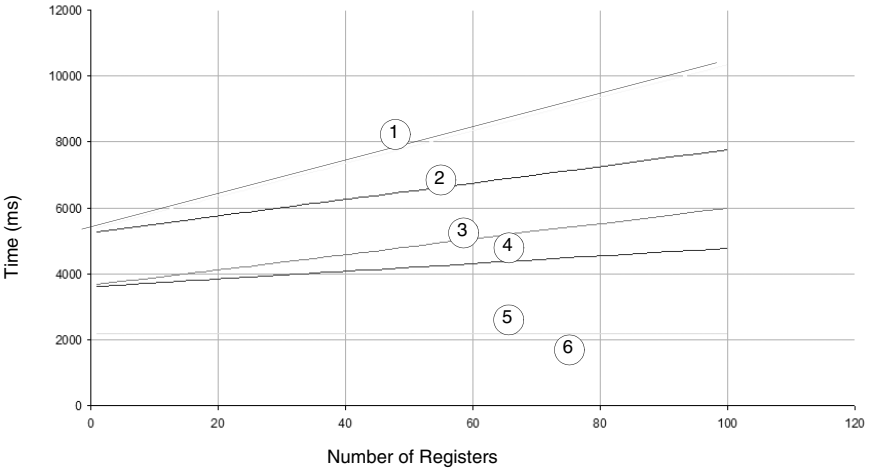
Serial Devices with 100 ms Response Time



The table below shows the data points used to generate the graph represented above.

Device	Serial Server Response TIme = 100						
CEV30020	Time to Complete All Requests						
Baud Rate	9600			19200			
Number of Registers	1 Request	8 Requests	16 Requests	1 Request	8 Requests	16 Requests	Bridge Time
1	2151.33	2944.663333	3851.33	2144.67	2891.336667	3744.67	138
16	2151.33	3294.663333	4601.33	2144.67	3066.336667	4119.67	138
32	2151.33	3667.333333	5401.33	2144.67	3253.003333	4519.67	138
64	2151.33	4414.996667	7001.33	2144.67	3626.336667	5319.67	138
100	2151.33	5254.663333	8801.33	2144.67	4046.336667	6219.67	138

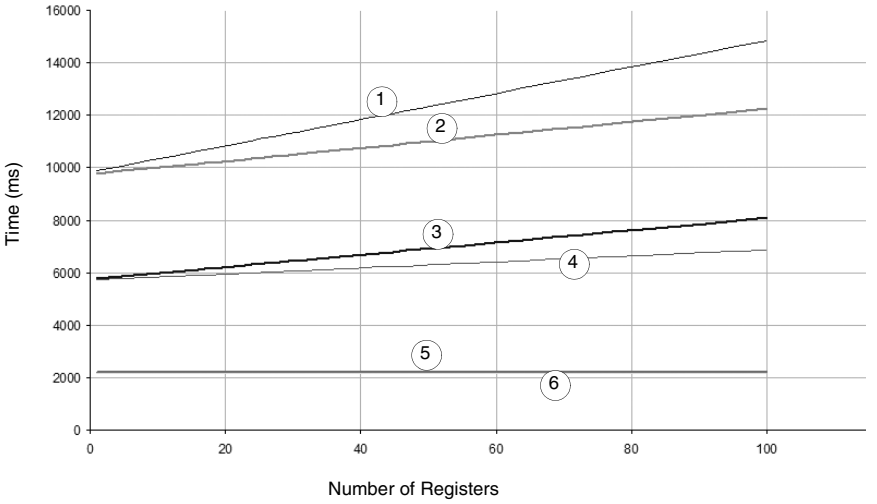
Serial Devices with 200 ms Response Time



The table below shows the data points used to generate the graph represented above.

Device	Serial Server Response TIme = 200						
CEV30020	Time to Complete All Requests						
Baud Rate	9600			19200			
Number of Registers	1 Request	8 Requests	16 Requests	1 Request	8 Requests	16 Requests	Bridge Time
1	2151.33	3644.663333	5351.33	2144.67	3591.336667	5244.67	138
16	2151.33	3994.663333	6101.33	2144.67	3766.336667	5619.67	138
32	2151.33	4367.333333	6901.33	2144.67	3953.003333	6019.67	138
64	2151.33	5114.996667	8501.33	2144.67	4326.336667	6819.67	138
100	2151.33	5954.663333	10301.33	2144.67	4746.336667	7719.67	138

Serial Devices with 500 ms Response Time



The table below shows the data points used to generate the graph represented above.

Device	Serial Server Response TIme = 200						
CEV30020	Time to Complete All Requests						
Baud Rate	9600			19200			
Number of Registers	1 Request	8 Requests	16 Requests	1 Request	8 Requests	16 Requests	Bridge Time
1	2151.33	5744.663333	9851.33	2144.67	5691.336667	9744.67	138
16	2151.33	6094.663333	10601.33	2144.67	5866.336667	10119.67	138
32	2151.33	6467.333333	11401.33	2144.67	6053.003333	10519.67	138
64	2151.33	7214.996667	13001.33	2144.67	6426.336667	11319.67	138
100	2151.33	8054.663333	14801.33	2144.67	6846.336667	12219.67	138

Standards and Other Considerations for Industrial Ethernet Networks

E

At a Glance

Overview

This appendix provides additional material in support of the standards and planning information presented in Chapter 2 (see *p. 27*).

What's in this Chapter?

This chapter contains the following topics:

Topic	Page
Standards and Organizations	480
Electromagnetic Compatibility	489
Copper Connector Standards Activities	493
Conforming to Standards	494
Transparent Ready Industrial Ethernet Conformance	496

Standards and Organizations

Standards Organizations

Several standards organizations develop generic cabling requirements. The Electronics Industries Alliance (EIA) and the Telecommunications Industry Association (TIA) develop and approve the LAN cable standards. Other groups develop network standards that affect cabling specifications.

Standards Organization	WebSite	Description	Area of Influence
EIA	www.eia.org	An association of seven electronics industry sectors and groups, including the TIA, CEMA, ECA, EIG, GEIA, JEDEC, and EIF.	U.S. and Canada
TIA	www.tiaonline.org	An association of mostly U.S. and Canadian companies that provides communications and information technology products, materials, systems, distribution services, and professional services.	U.S. and Canada
IEC (International Electrotechnical Committee)	www.iec.ch	International standards and conformity assessment body for all fields of electro technology.	Worldwide
ISO (International Standards Organization)	www.iso.org	Worldwide federation of national standards institutes from 146 countries. Cabling standards is a very small part of the ISO's total responsibilities.	Worldwide
CENELEC (Comité Européen de Normalisation Electrotechnique)	www.cenelec.org	Develops electro technical standards for the European Market/European Economic Area. Many CENELEC cabling standards mirror ISO cabling standards with minor differences.	Europe
Canadian Standards Association (CSA)	www.csa.ca	An association that works internationally to set standards for products and services through tests, certification, inspection for safety and performance, including EMC and IEC testing.	Canada
IEEE 802.3 (International Electrical and Electronics Engineers)	www.ieee.org	A working group that develops standards for CSMA/CD (Ethernet) based LANs, including 1000Base-T and 100Base-T.	Worldwide
ANSI	www.ansi.org	Facilitates development of the American National Standards. ANSI is the sole U.S. representative and dues-paying member of the two major non-treaty international standards organizations, ISO and IEC (via the U.S. National Committee (USNC)). Through ANSI, the U.S. has immediate access to the ISO and IEC standards development processes.	Worldwide

Standards Organization	WebSite	Description	Area of Influence
Internet Engineering Task Force (IETF)	www.ietf.org	IETF is a large open international community of network designers, operators, vendors, and researchers concerned with the evolution of the Internet architecture and the smooth operation of the Internet. It is the organization taking care of the Internet suite of protocols (TCP/IP)	Worldwide
Internet Assigned Numbers Authority	www.iana.org	Dedicated to preserving the central coordinating functions of the global Internet: protocol number assignment, domain name assignment.	Worldwide

Other industrial Ethernet organizations provide recommendations and support these standards organizations, but they do not define standards.

Internet Suite of TCP/IP Standards

The IETF is an IT organization that takes care of the TCP/IP suite. This organization manages the evolution of protocols such as TCP, IP, UDP, SNMP, HTTP, and FTP.

Requirements for Internet Hosts Communication Layers	RFC 1122 IETF Network Working Group, R. Branden, Ed., RFC-1122 (STD-0003), October 1989

Modbus Industrial Application Protocol Standard

Modbus Application Protocol Specification	Modbus-IDA - Version 1.1a, June 2004IEC PAS

TIA/EIA-568-A Standard

TIA/EIA-568-A is one of the first cabling standards. It was developed jointly by TIA and EIA to define the wiring system for voice and data networks as a structured, hierarchical star-topology network in which high-speed (fiber optic) cables feed slower peripheral networks. The standard was incorporated into TIA/EIA-568-B in 2000.

Standard	Focus	Description
TIA/EIA-568-A-1995	Commercial building telecommunications Wiring standards	Defines a standard for building cable systems for commercial buildings that support data networks, voice, and video. It also defines technical and performance criteria for cabling.
TIA/EIA-568-A (1998-1999)	Updates	A1 outlines propagation delay and delay skew parameters. A2 specifies miscellaneous changes. A3 defines requirements for bundled and hybrid cables. A4 defines NEXT and return loss requirements for patch cables. A5 defines performance requirements for Enhanced Category 5 (CAT5e).
TIA/EIA-568-B.1-2000	Commercial building telecommunications Wiring standards	Incorporates previous updates into a new release and specifies Category 5e cable as preferred due to its performance. Several addenda specify technical information for 100 Ω twisted-pair cable, shielded twisted-pair cable, and optical fiber cable.
ANSI/TIA/EIA-568-B.2	100 Ω twisted-pair cabling standard	
ANSI/TIA/EIA-568-B.3	Optical fiber standard	
TIA/EIA-569-A-1995	Commercial building standard for telecommunications pathways and spaces	Specifies how to build pathways and spaces for telecommunication media.
TIA/EIA-606-1994	Building infrastructure administration standard	Defines design guidelines for managing a telecommunications infrastructure.
TIA/EIA-607-1995	Grounding and bonding requirements	Defines grounding and equipotential bonding requirements for telecommunications cabling and equipment.
ANSI/EIA/TIA-570-A	Residential telecommunications cabling standard	

The TIA/EIA standards define a structured cabling system that is designed and built in multiple blocks. The blocks are integrated into a hierarchical network to create a unified communication system. LANs represent blocks with lower-performance requirements while backbone network blocks, which require high-performance fiber optic cable, perform the work of connecting the blocks to each other in a star-topology. The standard also specifies the requirements for fiber-optic (single and multimode), STP, and UTP cable.

In general, the TIA/EIA 568 wiring standard provides:

- specifications for a generic telecommunications wiring system for commercial buildings
- specifications for media, network topology, termination and connection (grounding) points, and administration of wiring systems
- support for environments that use several different products and vendors
- information about planning and installing a telecommunications network for buildings

ISO/IEC IS 11801 and EN 50173 Standards

The ISO/IEC 11081 and EN 50173 standards define the structure and configuration of cabling systems for office buildings and campuses. They are almost identical in scope and content, have the same terminology, and provide the same technical information. This generic cabling system is application-independent and consists of an open system of cabling components that are easy to implement. The cabling system described in the standard supports a range of services including voice, data, image, and video.

This table summarizes updates to the ISO/IEC-11801 standard.

Standard		Description
ISO/IEC-11801:1995	Generic customer premises cabling	Based on the TIA/EIA-568 cabling standard; defines a telecommunications cabling system for office buildings and campuses.
ISO/IEC-11801:2000	Generic customer premises cabling, 2nd Edition	Released in 2000; updates earlier standard based on new releases of the TIA/EIA-568 standard.
Administration, documentation, records		ISO/IEC 14763-1
Planning and Installation practices		ISO/IEC 14763-2
Testing of optical fibre cabling		ISO/IEC 14763-3
Testing of copper cabling		IEC 61935-1

This table summarizes the EN 50173 and related standards.

European Standards Documents	**Reference**
Building Design Phase	
Application of Equipotential Bonding and Earthing in Buildings with Information Technology Equipment	EN 50310
Coding Design Phase	
Information technology - Generic cabling systems	EN 50173 (and/or EN 50098-1 or -2)
Planning Design Phase	
Specification and Quality Assurance	EN 50174-1
Installation planning and practices inside buildings	EN 50174-2
Installation planning and practices outside buildings	EN 50174-3
Testing of Installed Cabling	EN 50346
Application of Equipotential Bonding and Earthing in Buildings with Information Technology Equipment	EN 50310
Implementation Planning Phase	
Specification and Quality Assurance	EN 50174-1
Installation planning and practices inside buildings	EN 50174-2
Installation planning and practices outside buildings	EN 50174-3
Testing of Installed Cabling	EN 50346
Application of Equipotential Bonding and Earthing in Buildings with Information Technology Equipment	EN 50310
Testing of Installed Cabling	EN 50346
Operation Phase	
Specification and Quality Assurance	EN 50174 Part 1

The ISO/IEC-11801:2000 standard specifies cabling systems for commercial properties which may include one or more buildings on a campus. The standard defines the requirements for both copper and fiber optic cables. Although the standard's focus is office buildings, the principles of the standard are applicable to other types of installations.

In general, the ISO/IEC-11801 standard provides:

- the structure and minimum configuration for a generic cabling system
- performance requirements for individual cable links
- conformance requirements and verification procedures
- requirements of an installation

The standard does not cover specifications for cables used to connect application-specific equipment to a cabling system. Standard guidelines relate to performance and length of cables only as these have the most significant impact on transmission quality. Safety and EMC are also not covered in the standard. Related information in the ISO/IEC 11801 standard, however, may be useful in understanding regulations encountered in other standards documents.For a cabling installation to conform to the IEC11801 standard, the configuration must connect the following subsystems to create a generic cabling structure:

- Campus backbone - uses a campus distributor.
- Building backbone - uses a building distributor for each building.
- Horizontal cabling - uses floor distributors.

Electromagnetic Compatibility Standards

The main EMC standards organizations are:

- IEC - International Electrotechnical Commission (Geneva)
- CENELEC - European Committee for Electrotechnical Standardization (Brussels)

There are two major international standards for electromagnetic emission and immunity:

- IEC 61000-6-2: 1999 Electromagnetic compatibility (EMC) - Part 6-2: Generic standards - Immunity for industrial environments
- IEC 61000-6-4: 1997 Electromagnetic compatibility (EMC) - Part 6: Generic Standards - Section 4: Emission standard for industrial environments.

The following table lists standards and publications that describe the requirements related to electromagnetic compatibility (see *p. 489*).

The following IEC publications table gives the equivalent European standards documents in brackets below each appropriate publication reference.

IEC Publications	Description
General	
IEC 1000-1-1 (1992)	Application and interpretation of fundamental differences and terms.
Environment	
IEC 1000-2-1 (1990)	Electromagnetic environment for conducted low-frequency (LF) interference and the transmission of signals over public supply networks.
IEC 1000-2-2 (1990)	Compatibility levels for conducted low-frequency (LF) interference and the transmission of signals over low-voltage public supply networks.
IEC 1000-2-3 (1992)	Radiated phenomena and conducted phenomena at frequencies other than mains frequencies.

IEC Publications		Description
IEC 1000-2-4 (1994)		Compatibility levels in industrial installations for conducted low-frequency interference.
IEC 1000-2-5 (1995)		Classification of electromagnetic environments.
Limits		
552-2	IEC 1000-3-2 (1995) [EN 61000-3-2 (1995)	Limits for rated harmonic current < 16 A per phase emitted by appliances.
552-3	IEC 1000-3-3 (1994) [EN 61000-3-3 (1995)]	Limitation of voltage fluctuations and flicker in low-voltage systems for equipment having a rated current equal to or less than 16 A.
	IEC 1000-3-5 (1994)	Limitation of voltage fluctuations and flicker in low-voltage systems for equipment having a rated current greater than 16 A.
Installation Requirements		
IEC 1000-5-1		General considerations
IEC 1000-5-2		Earthing and Wiring
IEC 1000-5-3		External Influences

IEC 1000-4 Standard

The IEC 1000-4 (previously known as IEC-801) standard establishes a "common reference for evaluating the performance of industrial-process measurement and control instrumentation when exposed to electric or electromagnetic interference."

The standard considers only those types of interference caused by sources external to the equipment. The standard describes interference susceptibility tests that demonstrate the capability of equipment to function correctly in its working environment. You determine the type of tests to run based on the types of interference to which your equipment is exposed when installed, taking into consideration the electrical circuit (that is, the way the circuit and shields are tied to earth ground), the quality of the shielding, and the environment.

The IEC 1000-4 standard is divided into six sections.

Test and Measurement Techniques		
801-1	IEC 1000-4-1 (1992-12) [EN 61000-4 (1994-08)]	Overview of immunity tests.
801-2	IEC 1000-4-2 (1995-01) [EN 61000-4-2]	Testing of immunity to electrostatic discharges.
801-3	IEC 1000-4-3 (1995-02) [ENV 50140 (1993)]	Testing of immunity to radiated radio frequency electromagnetic fields.
801-4	IEC 1000-4-4 (1995-01) [EN 61000-4-4]	Testing of immunity to high-speed burst transients.

Test and Measurement Techniques		
801-5	IEC 1000-4-5 (1995-02) [EN 61000-4-5]	Testing of immunity to impulse waves.
	pr IEC 1000-4-6 [ENV 50141 (1993)]	Immunity to conducted interference induced by radio frequency fields.
	IEC 1000-4-7 (1991-07) [EN 61000-4-7 (1993-03)]	Guidance on measurement of harmonics and interharmonics and measuring apparatus applicable to power supply systems and devices connected to them.
	IEC 1000-4-8 (1993-06) [EN 61000-4-8 (1993-09)]	Testing of immunity to mains-frequency magnetic fields.
	IEC 1000-4-9 (1993-06) [EN 61000-4-9 (1993-09)]	Testing of immunity to impulsive magnetic fields.
	IEC 1000-4-10 (1993-06) [EN 61000-4-10 (1993-09)]	Testing of immunity to damped oscillating magnetic fields.
	IEC 1000-4-11 (1994-06) [EN 61000-4-11 (1994-09]	Testing of immunity to voltage dips, brief power failures and voltage variations.
	pr IEC 1000-4-12	Testing of immunity to damped oscillating waves.

Automation Equipment standards

Programmable controllers part 2: Equipment requirements and tests	IEC 61131-2

TIA/EIA 568 Standards

The TIA/EIA-568-A standard is one of the first cabling standards, developed jointly by TIA and EIA. The TIA/EIA-568-A standard defined the wiring system for voice and data networks: a structured, hierarchical star-topology network in which high-speed (fiber optic) cables feed slower peripheral networks. The standard was incorporated into TIA/EIA-568-B in 2000.

This table summarizes updates to the TIA/EIA-568 standard.

Standard		Description
TIA/EIA-568-A-1995	Commercial Building Telecommunications Wiring Standards	Defines a standard for building cable systems for commercial buildings that support data networks, voice, and video. It also defines technical and performance criteria for cabling.

Standard		Description
TIA/EIA-568-A (1998-1999)	Updates	A1 outlines propagation delay and delay skew parameters.
		A2 specifies miscellaneous changes.
		A3 defines requirements for bundled and hybrid cables.
		A4 defines NEXT and return loss requirements for patch cables.
		A5 defines performance requirements for enhanced CAT5e).
TIA/EIA-568-B.1-2000	Commercial Building Telecommunications Wiring Standard	Incorporates previous updates into a new release and specifies Category 5e cable as preferred due to its performance. Several addenda specify technical information for 100-ohm twisted-pair cable, shielded twisted-pair cable, and optical fiber cable.
TIA/EIA-569-A-1995	Commercial Building Standard for Telecommunications Pathways and Spaces	Specifies how to build pathways and spaces for telecommunication media.
TIA/EIA-606-1994	Building Infrastructure Administration Standard	Defines design guidelines for managing a telecommunications infrastructure.
TIA/EIA-607-1995	Grounding and Bonding Requirements	Defines grounding and equipotential bonding requirements for telecommunications cabling and equipment.

The TIA/EIA standards define a structured cabling system that is designed and built in multiple blocks. The blocks are integrated into a hierarchical network to create a unified communication system. LANs represent blocks with lower-performance requirements, while backbone network blocks, which require high-performance fiber optic cable, perform the work of connecting the blocks to each other in a star-topology. The standard also specifies the requirements for fiber optic cable (single and multimode), STP, and UTP cable. In general, the TIA/EIA 568 wiring standard provides:

- specifications for a generic telecommunications wiring system for commercial buildings
- specifications for media, network topology, termination and connection (grounding) points, and administration of wiring systems
- support for environments that use several different products and vendors
- information about planning and installing a telecommunications network for commercial buildings

Electromagnetic Compatibility

Introduction

EMI can be an interfering electromagnetic noise, unwanted signal, or change in the propagation medium that can impair the performance of devices and equipment or of an entire system. It is one of the main causes of malfunction for communication networks in industrial environments. EMI can impact industrial applications in different ways, ranging from acceptable influence to damaged system components. During the installation process, you need to recognize EMI conditions and follow procedures that support electromagnetic capability and a safe environment.

This following discussion provides basic information about the types and sources of EMI and proposes solutions that can reduce EMI in environments where industrial machines and communication networks must coexist. Also included are the explanations of terminology and classifications.

Definitions

EMC is the ability of a device, equipment, or system to function satisfactorily in its electromagnetic environment without introducing intolerable disturbances to that environment or to other equipment. It requires that the interference emission level of equipment or devices in a system be low enough not to interfere with other equipment or devices located in the same electromagnetic environment. Because network wiring and equipment can be susceptible to and emit EMI, it also requires that the immunity level of equipment and devices be such that they are not disturbing and not being disturbed by other equipment in the environment.

EMI is any electromagnetic phenomenon capable of impairing the performance of a device, equipment, or system. It certain cases, the interference can be significant enough to damage the equipment beyond repair. In communication networks, unwanted EMI is simply an unwanted electrical signal that is added to the useful signal. This unwanted signal is sourced by conductions in conductors and by radiation in the air.

Disturbance or Interference

The terms *EMI* and *disturbance* mean essentially the same thing. A disturbance can be caused by an electromagnetic phenomenon such as electrical voltage, electrical current, and electrical or magnetic fields. It has a broad amplitude and frequency range over varying amounts of time. It results in the reduced ability of susceptible equipment to function.

Electro-magnetic Influence

Electromagnetic influence occurs each time a disturbance is transferred from an interference source through one or more coupling mechanisms to susceptible equipment. An interference source can be any device or equipment component that emits an electromagnetic disturbance such as electrical wiring, cables and communication devices, regulators and relays, and electric motors.

Susceptible equipment is any device or equipment component(s) that is capable of being influenced by EMI. Susceptible equipment has a *low immunity level* to EMI.

Coupling Mechanisms

Coupling is the spreading of EMI from its source to other susceptible equipment or devices. There are five types of coupling mechanisms.

Coupling Mechanisms	Description
Galvanic	Coupling through a common circuit
Inductive	Coupling through a magnetic field
Capacitive	Coupling through an electric field.; also called electrostatic coupling
Radiation influence	Coupling through an electromagnetic field
Wave Influence	Coupling through an electromagnetic field.

Interference can be transferred in a conductive (*guided energy*) form such as along a wire or through air (*unguided/radiated energy*). Interferences are normally found together as line-guided and radiated interference. In general, the same physical laws of energy transfer in electromagnetic fields apply to coupling interference.

The installation of an Ethernet for industrial application requires that you understand electromagnetic interference, coupling mechanisms, contributing influences, and proper preventive measures before you begin to install. Some of the ways you can decrease EMI and increase EMC in your installation are described in this chapter.

Ways to Decrease EMI

Depending on the type of coupling interference, you can use various methods to decrease or neutralize EMI. The following table shows methods appropriate for each type of coupling.

Methods	Galvanic Coupling	Inductive Coupling	Capacitive Coupling	Radiation Influence	Wave Influence
Grounding	X	-	-	-	-
Electrical Isolation	X	-	-	-	-
Balancing Circuits	-	X	X	X	-
Transposition of Outgoing/ Return Lines	-	X	X	X	-
Placement of Wires	-	X	X	X	-
Placement of Devices	-	X	X	X	-
Shielding	-	X	X	X	-
Filtering	X	X	X	X	X
Cable Selection	X	-	X	X	X
Wire Layout	X	X	X	X	X

Note: The two most efficient methods for decreasing EMI are shielding and wire layout. Both methods are described in this chapter.

Make sure you take the appropriate measures to

- reduce the transmission of electromagnetic disturbance from interference sources
- limit the spread of any electromagnetic disturbance

Types of Electromagnetic Interference

There are two main types of electromagnetic interference:

- low-frequency (LF)
- high-frequency (HF)

LF interference is encountered chiefly in conducted form, such as conduction in cables. It often has a long duration over several dozen milliseconds and in some cases may be continuous (harmonic). The conducted energy can be high and can result in the malfunction or even destruction of connected devices. The frequency range is $\leq$1 - 5 Hz.

HF interference is encountered chiefly in radiated form, such as electrostatic discharges in the air. The radiated energy is generally low and results in the malfunction of nearby equipment and devices. HF interference pulses with a pulse rise time of less than 10 ns. It can occur continuously, for example, in rectifiers and clocks. The frequency range is $\geq$30 MHz.

HF type interference may also encountered in conducted form as transient current or voltage. A transient is a temporary oscillation in a circuit that occurs as the result of a sudden change of voltage or load. For example, it could be caused by a lightning strike or an electrical fault. Electrostatic discharges disturbances can also be conducted along conductors and easily injected into other conductors by radiation.

LF and HF Interference

The following table provides an overview of the sources of LF interference

Type	Possible Sources	Effects of EMI
Harmonic Interference	inverters, choppers bridge rectifiers, electrolysis, welding machines, etc. arc furnaces induction ovens electronic starters electronic speed controllers for DC motors frequency converters for induction and synchronous motors domestic appliances such as televisions, gas discharge lamps, and fluorescent tubes	malfunction of connected devices potential destruction of connected devices

Type	Possible Sources	Effects of EMI
Low voltage mains interference	voltage fluctuation, brief power failures, voltage dip, surge voltages frequency variations waveform harmonics, transients, carrier currents phases, unbalanced power short circuits, overloads (effects on voltage)	malfunction of connected devices, such as high-speed relay dropout during voltage dips loss of power potential destruction of electronic hardware

The following table provides an overview of the sources of HF interference

Type	Sources	Effects of EMI
transients	lightning faults to earth commutation failures in inductive circuits (contractor coils, solenoid valves, etc.	malfunction of nearby equipment
Electrostatic discharge	between a person and an object between electrostatically charged objects For example, exchange of electrons between the body and fabric as a person walks across a carpet or of clothes worn by an operator sitting on a chair.	malfunction of nearby equipment potential destruction of equipment

The following table summarizes ways you can reduce EMI for LF versus HF disturbances

Preventive Measures for LF Phenomena	Preventive Measures for HF Phenomena
Protective systems Filtering Appropriate cable lengths	Equipotential bonding of exposed conductive parts (interconnections) Careful cable routing Selection of quality cables Proper connections for HF conditions Cable shielding
Protective systems are most important.	Installation practices are most important

Copper Connector Standards Activities

Current Activities

The IEC Subcommittee SC 48B is responsible for standardization of electronic connectors based on the requirements of IEC committees such as ISO/IEC JTC 1 SC 25 (standards for office and similar environments) and its Industrial Premises Cabling Task Group. These groups work together with the Subcommittee SC65C (Digital Communication) and are called the SC65C/JWG10 joint working group.

The SC65C/JWG10 working group's mission is to define the wiring and cabling of an Ethernet in industrial environments. It is important to note that standards defining the specifications for connectors already exist. The usage of these connectors in industrial Ethernet applications still needs to be standardized.Several networking organizations (Modbus-IDA, IAONA, PNO, ODVA) have made recommendations related to the type of copper connectors to use within different industrial environments. At the time of this writing, these are only recommendations and not standards.

Light Duty Industrial Connector Recommendations

For light-duty industrial environments, the market has accepted the use of RJ45 connectors, in accordance with the IEC 60603-7 standard. Some organizations have proposed the use of protective housings for the RJ45 (discussed by the IEC 61076-3-106).This topic is under heavy discussion due to the fact that there are multiple sealed RJ45 non-compatible models. The housings cover a variety of different mating dimensions (round or rectangular), locking mechanisms (screw, bayonet, locking lever, push/pull) and other special features. The different variants are not mateable.

Heavy Duty Industrial Connector Recommendations

For heavy duty environments, the choice seems to be the circular connector M12, already defined by the IEC61076-2-101 standard.The type of M12 connector to use is still under discussion due to the preference for 4 pins in Europe and the preference for 8 pins in the US. The 4-pin connectors are more prevalent in Europe which corresponds to the European practice of employing a 2-pair cable in Ethernet service, instead of the 4-pair cable specified by TIA, the US-based telecommunications standards body.

Conforming to Standards

Introduction

At this time, there is no international standard for planning and installing an industrial Ethernet network. There are recommendations from industrial Ethernet organizations and ongoing activities that have resulted in the creation of a draft for such a standard. Plans are to publish this standard as ISO/IEC 24702 by the end of 2006.

ISO/IEC 24702 and ISO/IEC 11801

Because the forthcoming ISO/IEC 24702 is based on the ISO/IEC 11801 standard, these existing standards can be used as references until ISO/IEC 24702 is published.

The ISO/IEC 11801 standard includes the following information:

Topic	Chapter (Clause)	Description
Structure of the generic cabling system	5	Describes the functional elements of a generic cabling system (campus distributor, building distributor, transition point, etc.) and how they are connected together.
Implementation	6	Specifies a cabling design that, when properly installed, conforms to the requirements of the International Standard. This section also defines maximum lengths.
Permanent link and channel specifications	7	Defines the permanent link and channel performance requirements of installed generic cabling systems. The section defines the: • Performance specifications of cabling for individual permanent links and channels • Performance specifications for two different media types (balanced cables and optical fiber) • Permanent channels and links and their classifications (5 classes, class D being an application of up to 100 MHz) • Performance specifications for the link/channel based on the application (performance around impedance, return loss, attenuation, etc.)
Cable requirements	8	Provides the requirements for cable used in horizontal and backbone cabling subsystems.
Connecting hardware requirements	9	Provides guidelines and requirements for connecting hardware used in generic cabling systems.
Shielding practices	10	Provides basic information about shielding.
Administration	11	Explains the identification, recording and documentation of a generic cabling system.

The final ISO/IEC 24702 standard will borrow the following chapters from standard ISO/IEC 11801:

- Chapter 7 - Link and Channel transmission classes for balanced cabling and fiber optic.
- Chapters 7, 8 and 9 - Component transmission performance for balanced cabling and fiber optic.

It will also add the following information based on industry requirements:

- A modification to the cabling structure specifications in the ISO/IEC 11801 Chapter 5.
- Environmental classification. (There is some limited information included in the ISO/IEC 11801 Chapter 10.)
- Suitable components
- Potential new concepts

ISO/IEC 11801 Conformance for Cabling Installations

The ISO/IEC 11801 standard defines conformance for cabling installations as follows: For a cabling installation to conform to this International Standard the following applies:

a The configuration shall conform to the requirements outlined in clause 5.

b The interfaces to the cabling shall conform to the requirements of clause 9.

c The entire system shall be composed of links that meet the necessary level of performance specified in clause 7. This shall be achieved by installing components which meet the requirements of clauses 8 and 9, according to the design parameters of clause 6, or by a system design and implementation ensuring that the prescribed performance class of clause 7, and the reliability requirements of clause 9, are met.

d System administration shall meet the requirements of clause 11.

e Local regulations concerning safety and EMC shall be met.

The ISO/IEC 11801 standard further states:

> The link performance specified in clause 7 is in accordance with clause 6 (installation). The link performance is met when components specified in clauses 8 and 9 are installed in a workmanlike manner and in accordance with supplier's and designer's instructions, over distances not exceeding those specified in clause 6. It is not required to test the transmission characteristics of the link in that case. Conformance testing to the specifications of clause 7 should be used in the following cases:
>
> - a. the design of links with lengths exceeding those specified in clause 6
> - b. the design of links using components different from those described in clauses 8 and 9
> - c. the evaluation of installed cabling to determine its capacity to support a certain group of applications
> - d. performance verification, as required, of an installed system designed in accordance with clauses 6, 8 and 9

Transparent Ready Industrial Ethernet Conformance

Application Classes

Application classes are defined by the ISO/IEC 11801 standard. Each application has a frequency range, and every application range has a recommended cable category. This table shows each of the classes and their associated application and cable category.

Class	Application Class includes	Permanent Link and Channel	ANSI/TIA/EIA-568 Category
A	Speech band and low-frequency applications Copper cabling permanent links and channels Supporting Class A applications are referred to as Class A permanent links and Class A channels, respectively	specified up to 100 kHz	-
B	Includes medium bit rate data applications Copper cabling permanent links and channels supporting Class B applications are referred to as Class B permanent links and Class B channels, respectively	specified up to 1 MHz	-
C	Includes high bit rate data applications Copper cabling permanent links and channels Supporting Class C applications are referred to as Class C permanent links and Class C channels, respectively.	specified up to 16 MHz	Category 3
D	Includes very high bit rate data applications Copper cabling permanent links and channels Supporting Class D applications are referred to as Class D permanent links and Class D channels, respectively	specified up to 100 MHz	Category 5 (No longer recognized by TIA/EIA) Category 5e (Recommended as the minimum for all future installations by: TIA/EIA, IEEE, Active Equipment Manufacturers.
Optical Class	Includes high and very high bit rate data applications Optical fibre permanent links and channels Supporting Optical Class applications are referred to as Optical Class permanent links and Optical Class channels, respectively	specified to support applications specified at 10 MHz and above.	-

Maximum Channel Lengths

This table shows the maximum channel lengths by cable category and class as defined by the ISO/IEC 11801 standard.

ISO/IEC Maximum Channel Lengths by Cable Categories and Class							
Media	Class A	Class B	Class C	Class D	Class E	Class F	Optical
CAT 3	2 km	200 m	100 m	-	-	-	-
CAT 4	3 km	260 m	150 m	-	-	-	-
CAT 5e	3 km	260 m	160 m	-	-	-	-
CAT 6	-	-	-	-	100 m	100 m	-
CAT 7	3 km	290 m	180 m	120 m	-	-	-
150 ohm	3 km	400 m	250 m	150 m	-	-	-
	-	-	-	-	-	-	-
Cable	-	-	-	-	-	-	-
62.5/125 and 50/125 mm	-	-	-	-	-	-	2 km
Optical Fiber	-	-	-	-	-	-	-
Singlemode	-	-	-	-	-	-	3 km

The class D link performance limits are listed in Annex A of EN 50173:2002 and ISO/IEC 11801:2002. The measurement limits are described in prEN 50346:2001.

Earthing (Grounding) Procedures

F

At a Glance

Overview

This appendix describes procedures for earthing (grounding).

What's in this Chapter?

This chapter contains the following topics:

Topic	Page
Well-made Earthing (Ground) Connections	500
Making an Earthing Connection	501
Cable Shielding Connection Options	507
Copper Ethernet Testing Procedures	509
Performance Parameters	510
Definitions of Performance Parameters	512

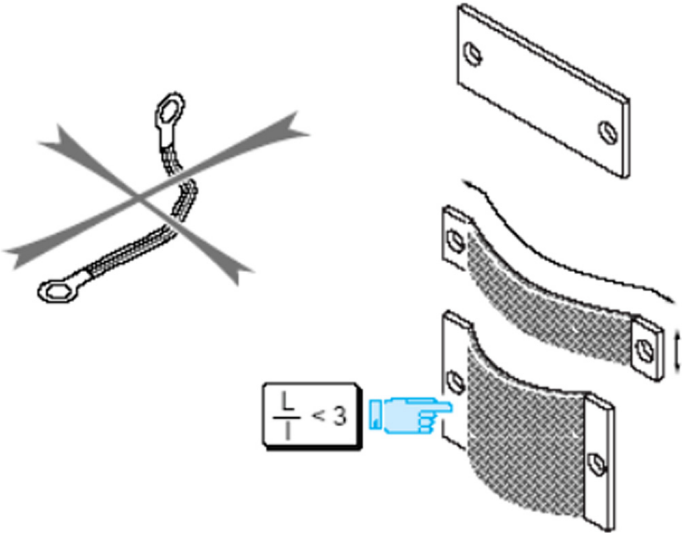
Well-made Earthing (Ground) Connections

Introduction

When you connect metal structures and equipment to an earthing system, the quality of the earthing connections is critical in protecting your equipment and achieving EMC. Earth connections use conductive straps, bars, bolts and cable fasteners to interconnect the metal components of machines, equipment, cabinets, cables shields, and other conductive objects to your earthing system.

Type and Length of Connections

When choosing the type of connection, frame earth connections must be as short and wide as possible in every case.



Note: Make sure that connections are properly made and that all exposed metal components are properly grounded. A well-made connection has the LF and HF conductive properties you require and promotes a long service life for your equipment.

Making an Earthing Connection

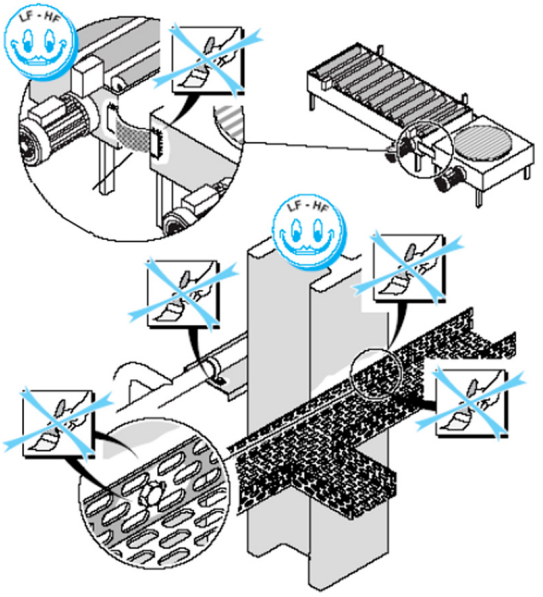
Introduction

You can make two types of earthing connection:

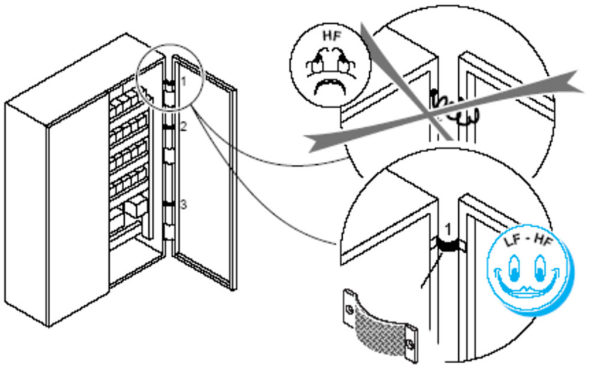
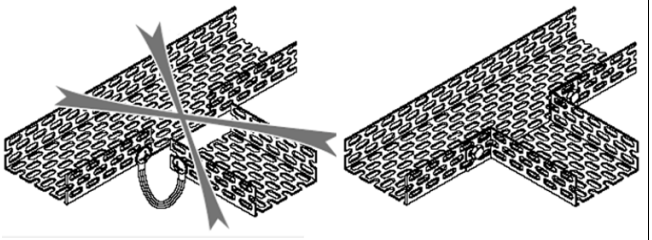
- between two metal surfaces
- between shielded cable and a metal surface

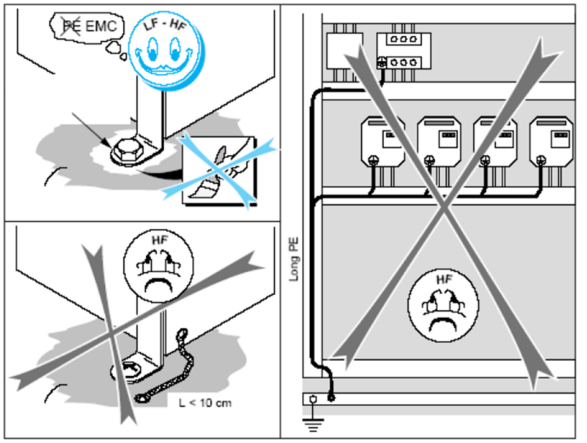
Making a Connection Between Two Metal Surfaces

Make sure that earth plane plates are not coated with paint or any other type of insulating covering. These materials prevent direct contact with other metal surfaces in an earthing system:



Follow these steps to make an EMC-compliant connection between two metal surfaces.

Step	Action	Comments
1	Select appropriately conductive connection materials for optimum contact. Use braided straps or bolts to connect metal surfaces. A metal plate or bar is less preferable but may be used in the absence of a braided strap. Do not use green/yellow wire conductors.	Here is a braided strap connection:  Here is a bolt, nut, and washer connection: 
2	Prepare the surface for metal connections at all contact points. Remove any paint or insulating coatings from the surface of metal contact points.	This includes the surfaces between any two continuous connections that are placed in contact, such as two flat metal sheets or bars
3	Attach connection surfaces using braided straps or nuts, bolts and washers.	Make sure the connection between contact surfaces is tight by using a nut and bolt system with a washer.

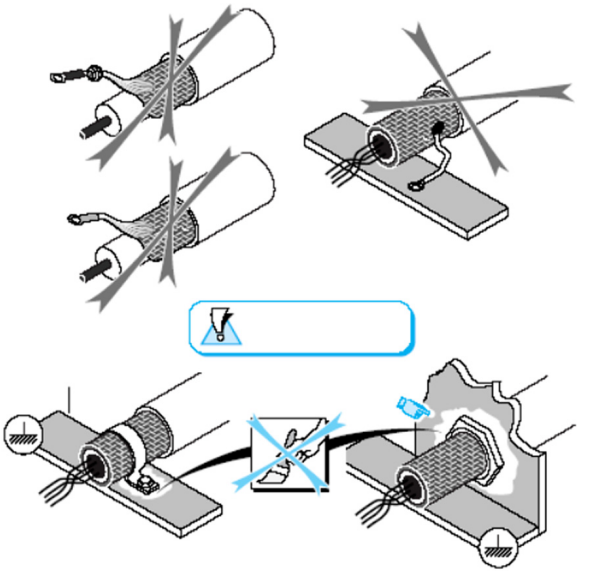
Step	Action	Comments
4	Make sure all metal components are interconnected and attached to an earthing system.	Recheck your connections to make sure they create a local earthing system that attaches to the earthing main conductor for your building (see *p. 96*). 
5	Apply a coating of paint or grease on nuts and bolts at each contact point to protect against corrosion.	Maintain the connection over time.

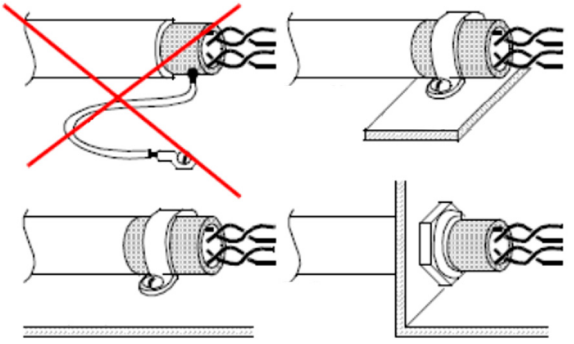
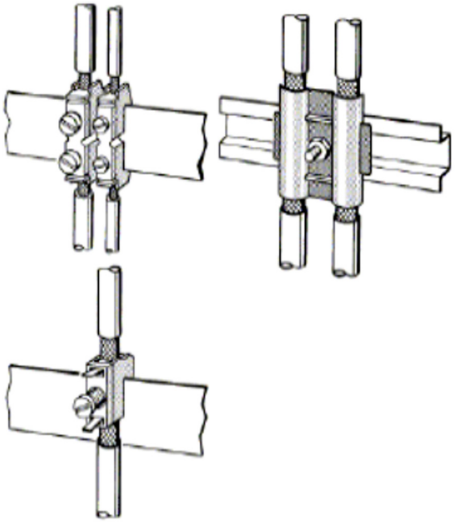
Connection Notes

- Paint, locking compounds and Teflon tape act as insulating materials and prevent clean contact between metal surfaces at connection points. If a cabinet or metal surface, including the bottom plate, has been painted, remove the paint before making a connection. After the connection is made, you may paint the connection materials to prevent corrosion.
- Make sure all exposed metal components and units that are fitted in a cabinet are bolted directly onto the earth plane plate.

Making a Connection Between Cable Shielding and Metal Surfaces

Because Ethernet operates at frequencies higher than 10 MHz, you must ground cable shielding at both ends to obtain maximum EMC effectiveness. If your site does not have equipotential bonding, you can make a connection to one end only and still provide acceptable, but not as effective, operation. Follow these steps to create a quality connection between a cable shielding and a metal surface.

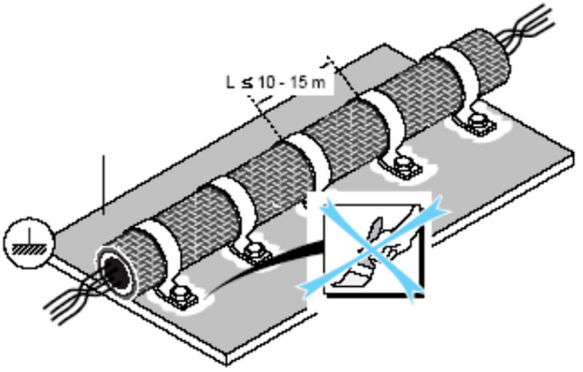
Step	Action	Comments
1	Select the appropriate cable for a Transparent Ready installation.	Schneider Electric strongly recommends that you use STP cable, at least CAT5, for any Transparent Ready installation. Schneider Electric also recommends that you use shielded connectors on cables, devices, and switches.
2	Install an earth bus bar or plane connected to a chassis to which you will attach the cable shielding. You can also attach cable shielding at entry points to cabinets.	Make sure there is no insulating covering or paint on the surface to which plan to attach the cable. Do not use soldered cable lugs or tinned leading-out wires to connect cable shielding. If possible, plan to connect the cable shield to an earth bus bar or at the point of entry to a cabinet.  In all cases, make sure you have allowed for a strong metal-to-metal contact that surrounds the cable 360 degrees.
3	Check the cable to make sure you have an uninterrupted cable shield from end to end.	If the cable is damaged or the cable shielding is cut, replace the entire length of cable.

Step	Action	Comments
4	Remove the outer plastic jacket to expose the internal cable sheath.	An excellent metal-to-metal contact must exist between the mesh cable shielding and the metal bus bar or earth plane. Expose the cable shield so that it has a 360-degree contact surface to make a good ground connection. 
5	Attach the cable shield. If possible, connect the cable shield to an earth bus bar or at the point of entry of a cabinet. Wherever possible, ground both ends of a cable by attaching them properly to an earth plane.	Make sure the connection at the end of the cable shielding provides a metal-to-metal bond that circles the sheath a full 360 degrees. You can use metal cable clips to fasten mesh shielding and get complete 360-degree contact.  Check that no paint or insulating coating exists between contact surfaces.

Connection Notes

- Avoid using poor connections from the cable sheath to a metal earth bus bar or plane.
- Remove any insulating plastic tape between the cable shielding layer and the sheath.
- Avoid using long cable shielding lengths. Shielding loses its effectiveness if the cable is too long. To optimize the effectiveness of shielding, provide a large number of intermediate connections to the earthing frame.

This diagram shows a cable with multiple connections to the earthing frame.



Cable Shielding Connection Options

Two Ways to Ground a Cable Shield

⚠ CAUTION

Exposure to low voltage.

When grounding a cable shield at only one end, there is a potential difference between the shielding and the ground connection of the unearthed end.

- Avoid contact.

Failure to follow these instructions can result in injury or equipment damage.

There are two ways you can ground a cable shield:

- create earthing connections at both ends of the cable
- create earthing connections at only one end of the cable
  The use of shielded cable without earthing connections is not recommended. Without a n earthing connection, the shielding is ineffective against magnetic fields and both HF and LF disturbances. Any possible contact with the cable shield creates a potential safety issue because of the potential difference between the shielding and the ground.

Advantages and Disadvantages

The following table describes the advantages and risks associated with these two earthing methods. Use this information to help you decide what is the best earthing connection choice for your installation.

Ground Connection Method	Advantages	Restrictions
Earthing connection on both ends of the cable	Extremely effective against external LF and HF disturbances	Ground-fault current can be induced in high-frequency signals with high interference-field strength for long cables (>50 m).
	Very good shielding effectiveness against resonance frequency on the cable	
	No potential difference between cable and ground	
	Enables common laying of cables that feed different class signals.	
	Very good suppression of HF disturbances	
Earthing connection on only one end of the cable	Average shielding effectiveness	Ineffective against external disturbances caused by high-frequency electric fields
	Enables protection of isolated lines against low-frequency electric fields	Shielding can cause resonance due to the antenna effect. This means the disturbance is greater than when shielding is present
	Enables buzz (low-frequency disturbance) to be avoided	

Shielded Cable Ground Loops

One of the risks of earthing cable shields at both ends is the creation of ground loops. Ground loops occur when current circulates through the shield due to the different potential between the extreme ends of the shield. If this happens, you need to achieve the same potential at both ends. If you are working with an existing installation, consider laying a binding conductor in parallel to the network cable. For very long distances, use fiber optic cable.

Copper Ethernet Testing Procedures

Introduction

The following discussion describes verification of installations, such as wiring and proper lengths, and references specifications for the testing of performance defined in Chapter 7 of ISO/IEC 11801.

Copper Installation Testing

Make sure to test copper wiring for:

- correct pin termination at each end
- continuity to the remote end
- short circuits between any two or more conductors
- crossed pairs
- split pairs
- reversed pairs
- shorted pairs
- other miswiring

Copper Performance Testing

The ISO/IEC 11801 standard requires that you test both channel and permanent links as follows:

- The performance of the channel is specified at and between interfaces to the channel
- The performance of a permanent link is specified at and between interfaces to the link

The ISO/IEC 11801 also states:

> The link performance is met when components specified in clauses 8 and 9 (of the ISO/IEC 11801) are installed in a workmanlike manner and in accordance with supplier's and designer's instructions, over distances not exceeding those specified in clause 6 (of the ISO/IEC 11801).

Performance Parameters

Introduction

Vendors of components and cables are required by the ISO/IEC 11801 standard to publish performance parameters for their products. The standard states that vendors of cables and components are required to present parameters for the different components of a permanent link or channel (whose specifications are defined in chapters 8 and 9 of the ISO/IEC 11801). The performance parameters specified by the ISO/IEC 11801 apply to permanent links and channels with shielded or unshielded cable elements (i.e., with or without an overall shield, unless explicitly stated otherwise). STP and UTP are also referred to as balanced cabling. Performance parameters are defined for 5 application classes. For example, class D applications are related to class D permanent links and channels, which are specified up to 100 MHz.

Specification Parameters and Related Standards

The following table lists all parameters proposed and/or required for testing and their associated standards. The most important standards for industrial Ethernet networks are in the last two columns.

Standard	**ISO/IEC 11801-2000**	**TIA/EIA 568B**	**ISO/IEC 11801-2000+**	**Addendum to TIA/EIA 568-B**
Status	Approved	Approved	Draft	Draft
Class or Category frequency range	Cl. C: 16 MHz Cl. D: 100 MHz	CAT 3:16 MHz CAT 5e: 100 MHz	Cl. C 16 MHz Cl. D: 100 MHz Cl. E: 250 MHz Cl. F: 600 MHz	CAT 3: 16 MHz CAT 5e: 100 MHz CAT 6: 250 MHz
Wire Map	x	x	x	x
Length		x		x
Propagation delay	x	x	x	x
Delay skew	x	x	x	x
Insertion loss attenuation	x	x	x	x
PP NEXT loss	x	x	x	x
PS NEXT loss	x	x	x	x
PP ACR	x			
PS ACR	x			
PP ELFEXT	x	x	x	x
PS ELFEXT	x	x	x	x
Return Loss	x	x	x	x
DC resistance	x		x	

List of Parameters

The following parameters are required in the testing and performance measuring of balanced cabling permanent links and channels:

- nominal impedance (see *p. 512*)
- return loss (see *p. 512*)
- attenuation (see *p. 512*)
- pair-to-pair NEXT loss (see *p. 513*)
- power sum NEXT (see *p. 514*)
- pair-to-pair ACR (see *p. 514*)
- power sum ACR (see *p. 514*)
- pair-to-pair ELFEXT (see *p. 514*)
- power sum ELFEXT (see *p. 514*)
- DC loop resistance (see *p. 515*)
- propagation delay (see *p. 515*)
- delay scew (see *p. 515*)
- longitudinal-to-differential conversion loss (see *p. 515*)
- transfer impedance of shield

Definitions of Performance Parameters

Introduction

The following discussion describes each of the specification parameters defined in the ISO/IEC 11801.

Nominal Impedance

Impedance is a measure of the degree a component resists the flow of energy from a given source. The impedance of a cable is important in determining the load placed on the source and the efficiency of the signal transmission. A simple way to define nominal impedance is to measurer a component that does not reflect energy back to the transmitting source. When a transmitting system sees the nominal impedance as its load, all the energy that it transmits is absorbed by the receiving end. If it does not see the nominal impedance, part of the energy bounces back. In an ideal system, all the transmitted energy is absorbed by the receiving end. Impedance is measured in Ohms (Ω).

Return Loss

Return loss is a measure of the reflected energy caused by impedance that mismatches in the cabling system (impedance consistency). If the system that transmits energy does not detect an impedance equal to the nominal impedance, then there will be reflected energy (that is, the receiving end bounces back some energy). In such cases, there is an echo of the transmitted signal. Return loss is measured in decibels or as a percentage of signal strength.

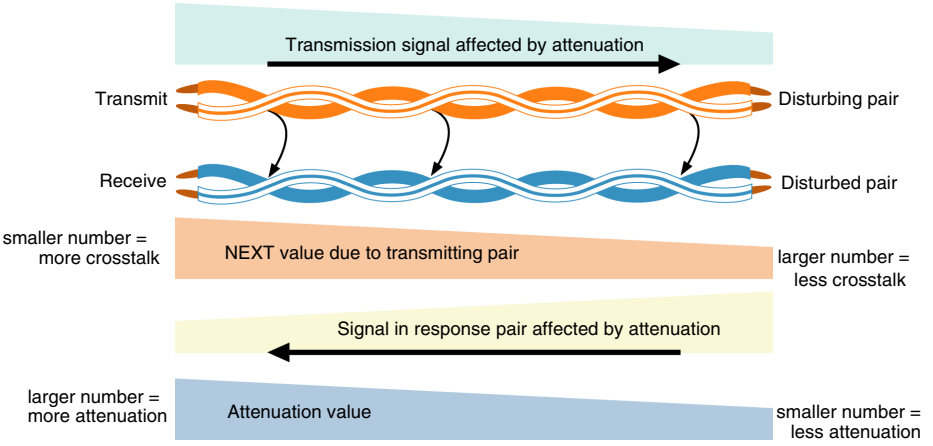
Attenuation (Insertion Loss)

Attenuation is the loss of signal strength as it travels along the cable. It is measured in decibels (dB). A low attenuation number is good—the lower the attenuation value, the stronger the signal. Attenuation depends on the cable length and the frequency. Attenuation increases as the cable length increases. It also increases as the frequency increases, and it is further affected by wire gauge. Thicker cables have less attenuation than thinner cables. Problems with attenuation are usually related to the use of thin cables, bad terminations, or long cables. Attenuation also increases with temperature.

Pair-to-pair Near-end Crosstalk Loss

Near-end crosstalk (NEXT) is the coupling of a signal from one pair (the disturbing pair) to another pair (the disturbed) measured at the end where the signal is injected (the near end). NEXT represents how much of the transmitted signal in the disturbing pair gets electromagnetically coupled in the disturbed pair. It is measured in the disturbed pair at the transmitting end. NEXT is measured in dB. A high NEXT value is good because it indicates high attenuation from one pair to another. NEXT varies with the frequency. It needs to be measured within a range of frequencies.

The figure below is an example of NEXT and attenuation values



The illustration shows two Ethernet pairs, transmit and receive. When the transmitting pair is energized it generates crosstalk to the receiving pair. At the near end, the signal in the receiving pair is the lowest and therefore more susceptible to the NEXT influence. As the value of NEXT increases, the value of attenuation also increases.

Twisted pair cables were developed to avoid crosstalk and allow opposing fields to cancel each other. The more twists there are, the better the cancellation and the higher the frequency supported by the cable. Often, the NEXT of a permanent link or channel decreases (indicating increased crosstalk) due to poor installation termination of cables. To connect the cable to a device, you must untwist the cable to access the wires. Untwisted wires increase crosstalk. You can minimize crosstalk by retaining the cable pair twists as much as possible when you terminate the cable and connect it to hardware.

Power Sum NEXT (PSNEXT)

Power Sum NEXT is the sum of all pair combinations for crosstalk measured at the Near End to the transmitter, and simulates all four pairs being operated simultaneously. It is the addition of the NEXT effects of three disturbing pairs in the fourth pair considered in the Near End. This parameter is intended for systems in which more than two pairs are used. PSNEXT varies with the frequency, and therefore, you need to measure it within a range of frequencies.

Pair-to-pair Attenuation of Crosstalk Ratio (ACR)

The attenuation of crosstalk ratio (ACR) is the difference between the NEXT and the attenuation in the pair under test. The formula is)

ACR = NEXT - Attenuation

At the near end, the NEXT is the strongest (smallest NEXT value) and the attenuation is the strongest (which means the largest attenuation and the lowest signal level). ACR is nearly analogous to the definition of signal-to-noise ratio. (ACR excludes the effect of external noise that may impact the signal transmission.

Power Sum ACR (PSACR)

Power sum ACR (PSAR) is a mathematical calculation that simulates all four pairs being operated simultaneously. The formula is:

PSACR = PSNEXT - Attenuation

Because PSACR is a measured signal to noise ratio, a larger number (more signal and less noise) is more desirable than a smaller number (more noise and less signal).

Far-end Crosstalk

Far-end crosstalk (FEXT) is similar to the NEXT. Even though the disturbing pair sends the signal from the local end, it is measured in the disturbed pair at the far end. The signal in the disturbing pair is weaker at the far end due to attenuation. Because the FEXT value is related to the attenuation of the cable, it is typically measured to obtain the ELFEXT, but not reported.

Pair-to-pair Equal-level Far-end Crosstalk

Equal-level far-end crosstalk (ELFEXT) is a mathematical calculation that is obtained by subtracting the attenuation of the disturbing pair from FEXT. This pair induces in an adjacent pair. The formula is:

ELFEXT = FEXT - Attenuation

Power Sum ELFEXT (PSELFEXT)

Power sum ELFEXT (PSELFEXT) is the sum of the values of the individual ELFEXT effects on each pair by the other 3 pairs. It is similar to the calculation used for PSNEXT. The calculation used to measure ELFEXT removes the impact of attenuation on FEXT.

DC Loop Resistance

DC loop resistance is the total resistance through two conductors looped at one end of the link. It is usually a function of the conductor diameter and varies only with distance. This measurement is sometimes done so that gross misconnections do not add significant resistance to the link.

Propagation Delay

Propagation delay is a measure of the time required for a signal to propagate from one end of the circuit to the other. Delay is measured in nanoseconds (ns). It is the principle reason for a length limitation on LAN cabling. In many networking applications, such as those employing CSMA/CD, there is a maximum delay that can be supported without losing control of communications.

Delay Skew

Propagation delay skew is the difference between the propagation delay on the fastest and slowest pairs in a UTP cable or cabling system.

Longitudinal-to-differential Conversion Loss (Balance)

Twisted-pair cable signal transmission assumes that the signals on each wire relative to earth ground are balanced. This means that anywhere along the length of the cable, the signal on one wire of a twisted pair, measured relative to earth ground, is exactly equal in amplitude, but exactly opposite in phase to the signal on the other wire of the same twisted pair.

If this ideal were true, there would be no RF signal emitted from the pair (no EMI/RFI), and coupling inside the link would be reduced. The normal NEXT is the result of the coupling of a differential signal applied to one pair showing up as a differential mode signal at the receive input. Other coupling mechanisms, that occur when the signal is not applied in a purely differential manner, include the differential mode to common mode coupling, common mode to differential mode coupling, and common mode to common mode coupling. These coupling mechanisms can be significant sources of excess NEXT. Therefore, this parameter defines how well the signal applied by the tester is balanced as it enters the link.

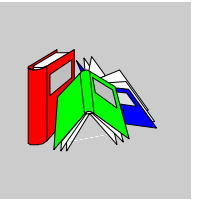
Parameter Values for CAT5 Cable from ISO/ IEC 11801

The following table lists the specification parameters and their Class D values for network links and channels.

Parameter	Permanent Link Class D	Permanent Channel Channel D
Frequency (it is presented at 100Mhz, but needs to measure over the 1-100Mhz range)	100 MHz	100 MHz
Maximum Attenuation	20.6 dB	24 dB
Minimum NEXT	29.3 dB	27.1 dB
Minimum Power-sum NEXT	26.3 dB	24.1 dB
Minimum ACR	8.7 dB	3.1 dB
Minimum Power-sum ACR	5.7 dB	0.1 dB
Minimum ELFEXT	19.6 dB	17.0 dB
Minimum Power-sum ELFEXT	17.0 dB	14.4 dB
Minimum Return loss	17 dB	17 dB
Maximum Propagation delay	489.6 ns	547.6 ns
Maximum Delay skew	43 ns	50 ns
Minimum Longitudinal to differential conversion loss	The measurement of these values on installed systems is not yet well established. It is sufficient to verify the values by design.	The measurement of these values on installed systems is not yet well established. It is sufficient to verify the values by design.

Parameter	Permanent Link Class D
Maximum Loop resistance (ohms)	40 Ω

Glossary



!

100BaseT4 100 Mb/s Ethernet running on four pairs of category 3, 4, or 5 unshielded twisted-pair cable.

10Base-F 10 Mb/s Ethernet running on optical fiber. 10BASE-F is a point-to-point network medium—e.g., hub/switch device-to-station.

10Base-T 10 Mb/s Ethernet running on unshielded twisted-pair cable. 10BASE-T is a point-to-point network medium—e.g., hub/switch device-to-station.

10Base2 10 Mb/s Ethernet running on thin coax network cable.

10Base5 10 Mb/s Ethernet running on thick wire network cable.

802 IEEE specifications for local area networks (LANs) and metropolitan area networks (MANs).

802.1 IEEE specifications for general management and internetwork operations such as bridging.

802.2 IEEE specifications that sets standards at the logical link control sub-layer of the data link layer.

802.3 CSMA/CD (Ethernet) standards that apply at the physical layer and the MAC sub-layer.

802.4 IEEE specifications for token passing bus standards.

802.5 IEEE specifications for token ring standards.

802.6 IEEE specifications for metropolitan area network (MAN) standards. IEEE 802 standards become ANSI standards and usually are accepted as international standards.

A

ack number A sender transmits a message in this **ack**nowlegement code to say that a message was received without errors.

ARP (*address resolution protocol*) A cache consisting of a table with matched hardware and IP addresses.

ATM *asynchronous transfer mode* A technology for high-speed transfer of voice, video and data over a network.

AUI (*attachment unit interface*) A 15-pin shielded, twisted pair Ethernet cable used to connect network devices and a medium attachment unit (such as a transceiver).

auto-negotiation/ auto-sensing The ability of a device (at the MAC sub-layer) to identify the speed (10 or 100 Mb/s) and the duplex or half mode of a connection and to adjust it, according to clause 28 of the IEEE 802.3u standard.

B

backbone The main cable of the network.

bandwidth The range of frequencies that a line transmission can carry. The capacity of a digital channel is measured in bits per second (bit/s).

baseband LAN A local area network that uses a single carrier frequency over a single channel. Ethernet uses baseband transmission.

bit/s Bits per second, unit of transmission speed.

BNC (*Bayonet Neill Concelman*) Standard connector used to link 10Base2 thin coaxial cable to a transceiver.

BootP (*bootstrap protocol*) A TCP/IP network protocol that offers network nodes request configuration information from a BOOTP server node.

BRI (*basic rate interface*) Of the two levels of service within ISDN, the one intended for residential and small business use. Consists of two 64 Kips B-channels and one 16 kbps D-channel for a total of up to 128 kbps of service.

bridge A networking device that connects two LANs and forwards or filters data packets between them, based on their destination addresses. Bridges operate at the data link level (or MAC layer) of the OSI reference model, and they are transparent to protocols and to higher level devices like routers.
Bridges connect networks that use dissimilar protocols and that operate at the data link level or layer 2 of the OSI model. They are often described as media-access control level (MAC layer) bridges. They do not carry out any interpretation of the information they carry. When two LANs are successfully bridged together, they become one effective LAN. Various load-balancing techniques have been developed to combat the problems of bandwidth limitation and the failure of any element on the network. Bridges are increasingly used to control network traffic so that the rest of the network is not involved. This boosts network performance and is also useful for security purposes.

bridge/router A device that can provide the functions of a bridge, a router or both concurrently. A bridge/router can route one or more protocols, such as TCP/IP and/or XNS, and bridge all other traffic.

broadcast A message that is sent out to all devices on the network.

broadcast domain A collection of devices that receive a broadcast sent on an Ethernet network. The broadcast domain ends at a router positioned in the network. If any device in a broadcast domain broadcasts information, that information is received by all devices in the same domain; it is not be received by devices connected through a router

Brouter A device that routes specific protocols, such as TCP/IP and IPX, and bridges other protocols, thereby combining the functions of both routers and bridges.

bus A LAN topology in which all the nodes are connected to a single cable. All nodes are considered equal and receive all transmissions on the medium.

C

CBN (*common bonding network*) The interconnected metallic components that comprise an earthing system in a building. Also known as an *integrated ground plane*.

CENELEC	*European Committee for Electrotechnical Standardization* in Brussels
channel	The end-to-end data path between two nodes. All cabling from one active device to another.
checksum	A redundancy check that typically adds up bytes to detect errors in a message.
CIDR	(*classless interdomain routing*) Also known as classless addressing or supernetting. A flexible method to allocate IP addresses less wastefully.
circuit switching	Maintaining a switch only while the sender and recipient are communicating.
circuit-switched network	A network that establishes a physical circuit temporarily until it receives a disconnect signal.
classless addressing	See CIDR.
coaxial cable	An electrical cable with a solid wire conductor at its center surrounded by insulating materials and an outer metal screen conductor with an axis of curvature coinciding with the inner conductor.
collision	The result of two network nodes transmitting on the same line at the same time. The transmitted data are not usable, so the stations must send again. A delay mechanism employed by both stations reduces the chances of another collision.
collision detection	A signal indicating that other stations are contending with the local station's transmission. The signal is sent by the physical layer to the data link layer on an Ethernet/IEEE 802.3 node. With Ethernet, each device can detect collisions and try to send the signal again. CSMA/CD is based on this principle.
communication server	A dedicated, standalone system that manages communications activities for other computers.
concentrator	A device that serves as a wiring hub in star-topology network.
ConneXium	Schneider family of Ethernet devices and solutions.
CRC	(*cyclical redundancy check*) A way of checking for errors in a message by doing mathematical calculations on the number of bits in the message, the results of which are sent along with the data to the recipient. The recipient repeats the calculation on the received data. If there are any discrepancies in the two calculations, the recipient requests a retransmission from the originator.

crosstalk Noise passed between communications cables or device elements. Near-end crosstalk is measured close to where the noise is introduced. Far-end crosstalk is introduced at one end and measured at the other.

CSMA/CD (*carrier sense multiple access with collision detection*) An Ethernet and IEEE 802.3 media access method. All network devices contend equally for access to transmit. If a device detects another device's signal while it is transmitting, it aborts transmission and retries after a random period of time.

CSU/DSU The *channel service unit/data service unit* prevents electrical interference while it transmits/receives signals to/from the WAN.T

cut-through Technique for examining incoming packets whereby an Ethernet switch looks only at the first few bytes of a packet before forwarding or filtering it. This process is faster than looking at the whole packet, but it also allows some bad packets to be forwarded.

D

data link A logical connection between two nodes on the same circuit.

data link layer Layer 2 of the seven-layer OSI reference model for communication between computers on networks. This layer defines protocols for data packets and how they are transmitted to and from each network device. It is a medium-independent, link-level communications facility on top of the physical layer, and is divided into two sub-layers—medium-access control (MAC) and logical-link control (LLC).

datagram A means of sending data in which parts of the message are sent in a random order and the recipient machine reassembles the parts in the correct order.

DCF A system of precision time signals sent from a transmitter near Frankfurt, Germany; used for time synchronization.

DCOM *distributed component object model* An extension of COM (Component Object Model) mode; DCOM mode is used for two remote machines to communicate with one another. It replaces inter-process communication protocols with network protocols. This is a Microsoft Windows standard.

DHCP (*dynamic host configuration protocol*) Communications protocol that assigns IP addresses to devices on the network, based on BootP.

distributed processing A system in which each station or node in the network performs its own processing and manages some of its data while the network facilitates communications between the stations.

DNS server/ service (*domain name server/service*) A service that translates a domain name into an IP address, the unique identifier of a device on the network.

DO (*device outlet*)

dongle A short network cable that connects a PCMCIA adapter to a network cable.

drop cable A cable that allows connection and access to the trunk cable in a network.a.k.a. *attachment unit interface (AUI) cable* or *transceiver cable*.

DSL (*digital subscriber line*) A high-speed Internet connection using normal telephone wires.

DVMRP (*distance vector multicast routing protocol*) A routing protocol used to support multicast that uses distance, as measured in routing hops, to determine a packet's optimal path.

E

EGP (*exterior gateway protocol*) Exchanges routing information, specifically routing tables, between two hosts on a network.

EMI (*electromagnetic interference*) Occurs when a device's operation is disrupted or degraded by the field of another nearby device.

encapsulation Wrapping a data set in a protocol header, for example, Ethernet data wrapped in a specific Ethernet header before network transit.
Also, a method of bridging dissimilar networks where the entire frame from one network is simply enclosed in the header used by the link-layer protocol of the other network.

EOS (*Ethernet over SONET/SDH*) Transfers Ethernet signals in SONET/SDH.

ERP (*enterprise resource planning*) A software system for businesses that manages planning, manufacturing and sales; also can include finances and human resources modules.

Ethernet A 10 or 100 Mb/s, CSMA/CD baseband LAN that may run over thin coax, thick coax, twisted pair or fiber optic cable. The IEEE standard 802.3 defines the rules for configuring an Ethernet network.

F

fault tolerance A network's ability to deter a failure on one part of the network from disrupting other network services. It increases network integrity and uptime.
Examples include redundant power supplies on transceivers, hubs and switches; simple or doubled-redundant optical or copper ring-topologies.

FDDI (*fiber-distributed data interface*) ANSI standard for using fiber optics to transmit data at up to 100 Mb/s over a network.
Originally specified for fiber lines, FDDI standards can also be used on short lengths of twisted-pair cable (a.k.a. *CDDI*).

FDR (*faulty device replacement*)

fiber optic cable A transmission medium composed of two glass optical (or plastic) fibers that transmits digital signals in the form of modulated light pulses from a laser or LED. Features a thin filament of glass, typically 125 to 140 μm in overall diameter Because of its high bandwidth and high immunity to interference, fiber optic cable is used in long-haul or noisy applications.

file server A computer that stores data for network users and provides network access to that data.

filtering With respect to Ethernet, a process whereby a switch or bridge reads the contents of a packet and, if it finds that the packet does not need to be forwarded, drops it. The *filtering rate* is the rate at which a device can receive packets and drop them without any loss of incoming packets or processing delay.

firewall A router or workstation with multiple network interfaces that controls and limits specific protocols, types of traffic within each protocol, types of services and the direction of information flow.

firmware The operating system (OS) of a device

FOIRL (*fiber optic inter-repeater link*) Signaling methodology based on the IEEE 802.3 fiber optic specification.

forwarding Process whereby an Ethernet switch or bridge reads the contents of a packet and passes the packet on to the appropriate attached segment. The *forwarding rate* is the time that it takes the device to execute all of the steps.

fragment With respect to Ethernet, a piece of a larger packet that has been broken down into smaller units.

fragmentation Breaking a packet into smaller units when transmitting over a network medium that cannot support the original size of the packet.

frame A group of bits sent over a link that contains its own control information, such as address and error detection. The size and composition of the frame varies by protocol. The terms *frame* and *packet* tend to used synonymously, although in strict OSI terms a frame is made at layer 2 and a packet at layer 3 or above.

frame relay A protocol using packet-switching to connect devices on a WAN.

framing Dividing data for transmission into groups of bits and adding a header and a check sequence to each group.

FTP (*file transfer protocol*) A TCP/IP protocol for file transfer.

FTP (*foil twisted pair*) Cabling with two conductors wound around each other to lessen crosstalk and a foil casing for added protection.

full duplex The ability of a device or line to transmit data independently and simultaneously in both directions.

G

gateway A combination of hardware and software that interconnects otherwise incompatible networks or networking devices. Gateways include packet assembler/disassembler (pads) and protocol converters. Gateways operate at layers 5, 6 and 7—the session, presentation and application layers, respectively—of the OSI model.

GMRP (*GARP multicast registration protocol*) A system allowing multi-cast of data; end stations receive data sent to the multicast group for which they are registered.

Gopher a network protocol for document search and retrieval which goes for information and uses a web of menu items like the holes of gophers to do so

GPS (*global positioning system*) A system of satellites and receiving devices used to calculate position on Earth.

H

half duplex Data transmission that can occur in two directions over a single line, but in only one direction at a time.

hardware address See network address.

head-end A central point or hub in broadband networks that receives signals on one set frequency band and retransmits them on another. Every transmission from one workstation to another in a broadband network must go through the head-end. It enables a network to send and receive on the same cable.

header The control information added to the beginning of a transmitted message. It contains essential information such as the packet or block address, source, destination, message number, length and routing instructions.

HMI (*human-machine interface*) The screen of a device, the design of which makes its use intuitive to the user.

host Generally a node on a network that can be used interactively, i.e., logged into, like a computer.

host table A list of TCP/IP hosts on the network and their IP addresses.

HSBY (hot standby system) This system is based on two identically configured programmable logic controllers linked to each other and to the same remote I/O network; If one controller fails, the other assumes control of the I/O system.

HTML (*hypertext markup language*) The code used to write web pages.

HTTP (*hyper text transfer protocol*) Protocol used to transmit files on the World Wide Web.

hub The center of a star topology network or cabling system. A multi-node network topology that has a central multiplexer with many nodes feeding into and through it. The other nodes do not usually interconnect directly. LAN hubs are becoming increasingly popular with the growth of twisted pair and fiber optics and with the need for LAN management.

hysteresis Until a plus or minus threshold around the value of a variable is exceeded, a signal to notify other systems of a change of state is suppressed.

I

I/O (*input/output*) The transfer of date to and from a computer.

ICMP (*Internet control message protocol*) This extension of the IP protocol is used to test a connection on the Internet with the *ping* command. It supports data packets with error, control and information messages.

IEC *International Electrotechnical Commission* in Geneva

IEEE 802.3 An *Institute of Electrical and Electronic Engineers* standard that defines the CSMA/CD media-access method and the physical and data link layer specifications of a local area network. Among others, it includes 10BASE2, 10Base5, 10Base-FL and 10Base-T Ethernet implementations.

IGMP *Internet group management protocol* This is the Internet standard for multicasting that allows a host to subscribe to a particular multicast group.

IGMP snooping Allows a switch to snoop, or listen in on, messages between a router and hosts.

inter-networking General term used to describe the industry composed of products and technologies used to link networks together.

Interbus An open communication standard that offers a high-speed network for the connection of I/O modules, sensors, actuators, and control devices to programmable logic controllers or large computer systems

interface broadcast mapping A proprerty that maps the rate of the broadcast traffic coming into each port of the managed switches.

Internet A series of interconnected local, regional, national and international networks, linked using TCP/IP. Internet links many government, university and research sites. It provides E-mail, remote login and file transfer services.

IP address The 32-bit address associated with a workstation in connection with TCP/IP Internet.

IP rating (*internal protection rating*) Describes the degree of protection for the internal circuitry of the sensors.

ISDN (*integrated services digital network*) A set of standards for digital transmission over copper telephone wires

ISO layered model The *International Standards Organization* sets standards for computers and communications. Its open systems interconnection (OSI) reference model specifies how dissimilar computing devices such as NICs, bridges and routers exchange data over a network. The model consists of 7 layers. From lowest to highest, they are: physical, data link, network, transport, session, presentation and application. Each layer performs services for the layer above it.

ISP (*Internet service provider*)

J

jabber Network error caused by an interface card placing corrupted data on the network. Also, an error condition caused by an Ethernet node transmitting longer packets than allowed.

JVM (*Java virtual machine*) Executes compiled Java code; sits on top of the operating system.

L

LAN (*local area network*) A data communications system consisting of a group of interconnected computers, sharing applications, data and peripherals. The geographical area is usually a building or group of buildings.

LAN segmentation Dividing *local area network* bandwidth into multiple independent LANs to improve performance.

latency With respect to Ethernet, the delay incurred by a switching or bridging device between receiving the frame and forwarding the frame.

layer With respect to networks, the software protocol levels that comprise the network's architecture, where each layer performs functions for the layer(s) above it.

line speed The maximum rate at which data can be transmitted reliably over a line using given hardware, expressed in bit/s.

link Physical connection between two nodes in a network. It can consist of a data communication circuit or a direct channel (cable) connection.

LLC (*logical link control* or *link layer control*) A data link protocol based HDLC, developed for LANs by the IEEE 802 Committee and common to all LAN standards for data link transmission (the upper part of ISO layer 2).

LNI (*local network interconnect*) A port multiplier or concentrator that supports multiple active devices or communications controllers, either stand-alone or attached to standard Ethernet cable.

logical link A temporary connection between source and destination nodes, or between two processes on the same node.

loss Also referred to as signal loss. The attenuation or degradation of a signal during transmission.

LS (*low smoke*) A cable's ability to avoid giving off toxic smoke in case of fire.

M

MAC (*media access control*) Generic term for the way in which workstations gain access to transmission media. Most widely used in reference to LANs.

MAC address The *media access control* address of a device, which is burned into a DNI card and is added near the beginning of the packet.

MAN (*metropolitan area network*) A network that spans a geographical area greater than a local area network but less than a wide area network. IEEE 802.6 specifies the protocols and cabling for a MAN. However, they could be superseded by ATM.

masquerading When a user appears to the system as another user. Can be used for malicious purposes. IP masquerading allows only the connection at the firewall or router to be seen on the Internet in order to hide a protected IP address space.

MAU (*medium attachment unit*) A device used to convert signals from one Ethernet medium to another. A transceiver is a MAU.

MES (*manufacturing execution system*) A computerized system that aids in managing data and communications for production flow.

MIB (*management information base*) A database of network parameters used by Simple Network Management Protocol (SNMP) and Common Management Information Protocol (CMIP) to monitor and change network device settings. It provides logical naming for all information resources on the network that pertain to network management.

MICE (mechanical, ingress, climatic, environmental) An international standardization effort by a collaborative group of experts from IEC TC65, TIA TR-42.9, and CENELEC TC215 WG1 to establish environmental standards for industrial Ethernet.

MII (*media-independent interface*) IEEE 802.3u standard for fast Ethernet. MII is the fast Ethernet equivalent of AUI in 10 Mb/s Ethernet—it allows different types of fast Ethernet media to connect to a fast Ethernet device via a common interface.

MMF (*multi -mode fiber*) A cable that passes light instead of electronic pulses. It supports point-to-point connections only, over a maximum length is 2 km. It has been classified as the best type of cable to use between buildings.

MPLS *multiprotocol label switching* Integrates information on Layer 2 into Layer 3, thereby allowing routing of traffic around system problems.

MSTR A function block used for programming.

MT-RJ A new standard connector for optical cables.

MTU (*maximum transmission unit*) The largest size packet a network can transmit, measured in bytes. The size is set by the network administrator and can be different for each network. Larger packets are divided before they are sent, but this slows transmission speed.

multi-port repeater A repeater, either stand-alone or connected to standard Ethernet cable, that interconnects up to 8 thin-wire Ethernet segments.

multicast A message sent out to multiple devices on the network by a host.
A special form of broadcast where copies of the packet are delivered to only a subset of all possible destinations.

N

name server Software that runs on network hosts charged with translating text-based names into numeric IP addresses.

Nano	Small range PLC platform from Schneider
network	An interconnected system of computers that can communicate with each other and share files, data and resources.
network address	Every node on a network has at least one address associated with it, including at least a fixed hardware address assigned by the device's manufacturer. Most nodes also have protocol-specific addresses assigned by a network manager.
network management	Administrative services for managing a network, including configuring and tuning, maintaining network operation, monitoring network performance, and diagnosing network problems.
NFS	(*network file system*) A protocol for file sharing among UNIX hosts.
NIC	(*network interface card*) An adapter card inserted into a computer that contains the necessary software and electronics to enable the station to communicate over the network.
NMS	(*network management system*) A manager, within SNTP, that can query and get responses from agents and set variables in them.
node	Any intelligent device connected to the network, including terminal servers, host computers and devices such as printers and terminals that connect directly to the network. A node can be thought of as any device that has a hardware address.
NTP	(*network time protocol*) A protocol in TCP used to synchronize time on devices across a network; uses signals from atomic and radio clocks.

O

OEM	(*original equipment manufacturer*) Buys computers in bulk, customizes them for a certain application and resells them under its own name.
OLE	(object linking and embedding) Microsoft software system that lets WIndows applications move and share information.
OPC	Specification for process control and manufacturing automation; defines standards for objects, methods and interfaces.

OSI (*open systems interconnect/interconnection*) A structure for internetworking heterogeneous computers for distributed application processing according to international standards.

OSI reference model A 7-layer network architecture model of data communication protocols developed by ISO and CCITT. Each layer specifies particular network functions such as addressing, flow control, error control, encapsulation and reliable message transfer.

OSPF (*open shortest path first*) A link-state routing protocol in which every switching node (router) passes a full map of network connections, used to calculate the best next hop, from one router to the next.

P

packet A series of bits containing data and control information, formatted for transmission from one node to another. It includes a header with a start frame, the source and destination addresses, control data, the message itself, and a trailer with error control data (called the *frame check sequence*).

packet-switched network A network in which data is transmitted in packet units. The packets can be routed individually over the best available network connection and reassembled as a complete message at the destination.

PCMCIA (*Personal Computer Memory Card International Associates*) Developers of a standard for a device card to add memory, use for a modem/fax or use as a portable disk drive.

physical address An address identifying a single node.

physical control layer Layer 1 in the system network architecture model.

physical layer Layer 1 (the bottom layer) of the OSI reference model is implemented by the physical channel. It governs hardware connections and byte-stream encoding for transmission. It is the only layer that involves a physical transfer of information between network nodes. The physical layer insulates layer 2 (the data link layer) from medium-dependent physical characteristics such as baseband, broadband or fiber optic transmission. Layer 1 defines the protocols that govern transmission media and signals.

physical media Any physical means for transferring signals between OSI systems. Considered outside the OSI Model, and sometimes referred to as Layer 0, or the bottom of the OSI Reference Model.

ping (*packet Internet groper*) To test the network by trying to reach a destination with an ICMP echo request and waiting for a reply, type *ping.exe* at the command line.

point-to-point A circuit connecting two nodes only, or a configuration requiring a separate physical connection between each pair of nodes.

port The physical connector on a device enabling the connection to be made.

port multiplier A concentrator that connects multiple devices to a network.

PPP (*point-to-point protocol*) A protocol that provides router-to-router and host-to-network connections over both synchronous and asynchronous circuits. The successor to SLIP.

PRI (*primary rate interface*) Of the two levels of service within ISDN, the one intended for larger enterprises. Consists of 23 B-channels and one 16 kbps D-channel in the U.S. or 30 B-channels and one D-channel in Europe.

print server A dedicated computer that manages printers and print requests from other nodes on the network.

protocol Any standard method of communicating over a network.

Q

QoS (*quality of service*) A performance specification for measuring and improving the transmission quality and service availability of a communications system.

R

rapid spanning tree (*RSTP*) An enhancement of spanning tree protocol that cuts convergence time; it reduces reconfiguration time and therefore restores service faster. See *spanning tree*.

RARP (*reverse address resolution protocol*) A protocol used to convert a hardware interface address into a protocol address.

RAS (*remote access server*/service) A server that offers remote access to a Local area Network (LAN), most commonly by use of a telephone line.

redundancy The duplication of critical components in order to increase reliability.

remote access Access to network resources not located on the same physical Ethernet, where the physical Ethernet refers to an entire site network topology.

remote control Form of remote access where a device dialing in assumes control of another network node; all keystrokes on the remote are translated into keystrokes on the network node. Used primarily with IPX protocol.

remote node Form of remote access where the device dialing in acts as a peer on the target network. Used with both IP and IPX protocols.

repeater A network device that connects one Ethernet segment to another within the same local area network. The repeater transmits signals both ways between the segments. It amplifies the electrical signals, regenerates the header of each packet, extends packet fragments and performs auto-segmentation and auto-reconnection on ports with continuous collisions.

ring A network topology in which the nodes are connected in a closed loop. Data move from node to node around the loop, always in the same direction.

RIO adapter Remote Input/Output CRP (communications processor to the remote devices)

RIO link Network communications across the remote input/output devices

RIP routing information protocol A distance vector protocol that uses distance in number of routing hops to calculate the best next path for a data packet.

RJ connector A *registered jack* connector type used with twisted pair UTP/STP, e.g., RJ45.

RMON (*remote monitoring*) A subset of SNMP. MIB II allows flexible and comprehensive monitoring and management capabilities by addressing up to 10 different groups of information.

RMON MIB (*remote monitor management information base*) The nine (Ethernet) levels of network management statistics reporting.

router Device capable of filtering/forwarding packets based on data link layer information. Whereas a bridge or switch may read only MAC layer addresses to filter, a router can read data such as IP addresses and route accordingly.
Unlike bridges, routers operate at level 3 (the network layer) of the OSI model. Also unlike bridges, routers are protocol specific, acting on routing information carried by the communications protocol in the network layer. Bridges pass layer 2 (data link) packets directly onto the next segment of a LAN, whereas a router can use information about the network topology and so can choose the best route for a layer 3 packet. Because routers operate at level 3, they are independent of the physical layer and so can be used to link a number of different network types. They have to be able to exchange information between themselves so that they know the conditions on the network; which links are active and which nodes are available.

router hop The route between one router and the next; all data packets specify the number of hops after which the packet will be dropped and an error message sent to the data source.

routing The process of delivering a message across a network or networks via the most appropriate path. While simple in principle, routing uses a specialized, complex science, influenced by a plethora of factors. The more networks are joined together, the more esoteric it is set to become.

routing bridge MAC layer bridge that uses network layer methods to determine a network's topology.

routing protocol Protocol that implements a specific routing algorithm.

routing table Table stored in a router or some other internetworking device that keeps track of routes (and, in some cased, metrics associated with those routes) to particular network destinations.

routing update Message sent from a router to indicate network accessibility and associated cost information. Routing updates are typically sent at regular intervals and after a change in network topology.

RTPS (*real-time publish-subscribe*) Enables the transfer of data and the transfer of state over unreliable protocols like UDP/IP.

S

SASL (*simple authentication and security layer*) Used to identify and authenticate a user to a server; can also protect further transmissions by inserting a security layer.

SCADA (*supervisory control and data acquisition*) Software that, interfacing with a programmable logic controller, gathers and analyzes information used to monitor and control commercial equipment

ScTP (*screened twisted pair*) Cabling with two conductors wound around each other to lessen crosstalk, a braided shield like STP, and an extra outer braid for added protection.

SDH (synchronous digital highway) Signal standard in digital transmission.

segment With respect to Ethernet, an electrically continuous piece of the bus. Segments can be joined together using repeaters or bridges.

segment delay The amount of time it takes a signal to propagate from one end of the segment to the distant end.

segmentation With respect to Ethernet, splitting an overloaded ring into two or more separate rings, linked by a bridge/router or multipurpose hub.

server A computer that provides resources to be shared on the network, such as files (file server) or terminals (terminal server).

session A connection to a network service.

shared Ethernet Ethernet configuration in which a number of segments are bound together in a single collision domain. Hubs produce this type of configuration, where only one node can transmit at a time.

signal loss See *loss*

SLIP (*serial-line Internet protocol*) A protocol for running TCP/IP over serial lines.

smart wiring hub A network concentrator that allows multiple media to be supported and managed from a central location. When supporting structured wiring systems, smart hubs provide port management.

SMF (*single-mode fiber*) A fiber with a small core diameter (approximately 3 μm) and a cladding with a refractive index very close to that of the core. It transmits light rays that enter at a narrow angle over very wide bandwidth. SMF has a relatively narrow diameter through which only one mode propagates. It carries higher bandwidth than MMF, but requires a light source with a narrow spectral width.

SMS (*short message service*) Text messages of up to 160 characters that can be sent to a wireless device.

SMTP (*simple mail transfer protocol*) Internet standard used to send and receive email messages.

SNA (*systems network architecture*) IBM's layered protocols for mainframe communications.

SNMP (*simple network management protocol*) A 3-part protocol comprising: structure of management information (SMI), management information base (MIB) and the protocol itself. The SMI and MIB define and store the set of managed entities; SNMP itself conveys information to and from these entities. The public domain standard is based on the operational experience of TCP/IP Internet works within DARPA/ NSFnet.
A TCP/IP host running an SNMP application to query other nodes for network-related statistics and error conditions. The other hosts, which provide SNMP agents, respond to these queries and allow a single host to gather network statistics from many other network nodes.

SNP (*sub-network protocol*) A TCP/IP protocol residing in the sub-network layer below IP. It provides data transfer through the local sub-net. In some systems, an adapter module must be inserted between IP and the SNP to reconcile their dissimilar interfaces.

SNTP (*simple network time protocol*) A simplified version of NTP, used to synchronize the clocks of computer systems.

SOAP (*simple object access code*)

socket A unique identifier, made up of an IP address and a port number, for an end-point of communication in a system/application.

SONET (*synchronous optical network*) Signal standard in digital transmission.

spanning tree (STP) A technique that detects loops in a network and logically blocks the redundant paths, ensuring that only one route exists between any two LANs; used in an IEEE 802.1d bridged network. See *rapid spanning tree.*

spanning tree algorithm An algorithm used by bridges to create a logical topology that connects all network segments and to ensure that only one path exists between any two stations.

spoofing A security attack in which an intruder sends a message using the stolen/hacked IP address of an identified host on the network in order to gain unauthorized access.

SQL (*structured query language*) Used to query (request data from) a relational database.

SSID	(*service set identifier*) A sequence of 32 letters or numbers in the packet header that uniquely identifies a wireless LAN.
star topology	A network where each workstation is connected to a central hub through a dedicated point-to-point connection.
store and forward	Technique for examining incoming packets on an Ethernet switch or bridge whereby the whole packet is read before forwarding or filtering takes place. Store and forward is a slightly slower process than cut-through, but it ensures that all bad or misaligned packets are eliminated from the network by the switching device.
STP	(*shielded twisted-pair*) Common transmission medium that consists of a receive (RX) and a transmit (TX) wire twisted together to reduce crosstalk. The shield is a braided outer sheath.
STU application file	Project file extension for Unity Pro software application
subnet	A interconnected, but separate, portion of a network that shares a network address with other portions of the network. Used for security and performance.
supernetting	See *CIDR.*
switch	A multiport Ethernet device designed to increase network performance by allowing only essential traffic on the attached individual Ethernet segments. Packets are filtered or forwarded based upon their source and destination addresses.
switched Ethernet	An Ethernet hub with integrated MAC-layer bridging or switching capability that provides each port with 10 Mb/s of bandwidth.Separate transmissions can occur on each port of the switching hub. The switch filters traffic based on destination MAC address.
switched virtual LAN	A logical network consisting of several different LAN emulation domains controlled through and intelligent network management application.
switching hubs	Hubs that use intelligent Ethernet switching technology to interconnect multiple Ethernet LANs and higher-speed LANs such as FDDI.
SYN	(*synchronize*) A packet type used by TCP to synchronize sequence numbers on two computers beginning a new connection.
SYN ACK	A message that *ack*nowledges the *syn*chronize message from the client and opens the socket from the server back to the client.

synchronous services The client application that calls a read or write service is blocked from further requests for the time it takes to obtain a result from the original request.

T

T-connector A T-shaped device with two female connectors and one male BNC connector.

tap connector Physical hardware that allows connection of a device, or new section of cable, to a trunk cable.

TCP/IP (*transmission control protocol/Internet protocol*) A set of protocols developed by the U.S. Defense Department's Advanced Research Projects Agency (ARPA) during the early 1970s. Its intent was to develop ways to connect different kinds of networks and computers. TCP/IP does not have the functionality that OSI provides.
TCP/IP is a transport and Internet working protocol—i.e., the de facto networking standard. It is commonly used over X.25 and Ethernet wiring and is viewed as one of the few protocols available that is able to offer a true migration path towards OSI. TCP/IP is able to operate in most environments. TCP/IP operates at Layers Three and Four of the OSI model (Network and Transport respectively).
TCP and IP are the standard network protocols in UNIX environments. They are almost always implemented and used together.

Telnet A terminal emulation program used to remotely control servers.

terminal server A concentrator that facilitates communication between hosts and terminals.

terminator A special connector used on both ends of a standard Ethernet or thin-wire Ethernet segment. It provides the cable with 50 Ω of termination resistance.

TFTP (*trivial file transfer protocol*) On computers that run TCP/IP networking software, TFTP is used to quickly send files across the network with fewer security features than FTP.

thick wire Half-inch diameter coaxial cable.

thin wire Coaxial cable similar to that used for television/video hookups.

time-out An interrupt signal sent by a device that has not received the input it has waited a given time for.

token-ring A computer network in which a bit pattern called a token is passed around a circular topology, or ring, of computers, in order to prevent collision of data between two computers trying to send messages at the same time.

topology The arrangement of the nodes and connecting hardware that comprises the network. Types include ring, bus, star and tree.

TP (*twisted-pair*) Cable consisting of two 18 to 24 AWG solid or stranded copper conductors, each coated in an insulating material, that are twisted together. The twisting provides a measure of protection from electromagnetic and radio-frequency interference.

trace route TraceRT is a route tracing tool used to measure the number of router hops, or routes, between systems to help locate problems; Type *tracert.exe* at the command prompt.

transceiver A network device capable of both transmitting and receiving messages. It serves as the interface between a user device and a network, so that it may actively convert signals between the network and the local node.

transceiver cable Cable that attaches a device either to a standard or thin coax Ethernet segment.

Transparent Ready services Schneider solutions for optimizing electrical distribution, industrial control and automation performance.

twisted-pair cable Inexpensive, multiple-conductor cable comprising one or more pairs of 18 to 24 AWG copper strands. The strands are twisted to improve protection against electromagnetic and radio frequency interference. The cable, which may be either shielded or unshielded, is used in low-speed communications, as telephone cable. It is used only in base-band networks because of its narrow bandwidth.

U

UDP (*universal datagram protocol*) A transport layer protocol for datagrams, used primarily for broadcasting. Also responsible for port addresses.

UL approval Tested and approved by Underwriters Laboratories, Inc.

UL cable certification

In conjunction with several manufacturers, UL has developed a data transmissions performance level marking program. This approval is printed on a cable as shown below:
Level I - performance is intended for basic communications and power-limited circuit cable.
Level II - performance requirements are similar to those for Type 3 cable (multi-pair communications cable) of the IBM Cabling System Technical Interface Specification (GA27-3773-1). These requirements apply to both shielded cable with two-to-25-pair conductors.
Level III - data cable complies with the transmission requirements in the EIA/TIA Wiring Standard for Horizontal Unshielded Twisted Pair (UTP) Cable and with the requirements for Category 3 in the proposed EIA/TIA 568A Standard. These requirements apply to both shielded and unshielded cables.
Level IV - cable complies with the requirements in the proposed National Electrical Manufacturer's Association (NEMA) Standard for Low-Loss Premises Telecommunications Cable. Level IV requirements are similar to Category 4 requirements of the proposed EIA/TIA 568A Standard. These requirements apply to both shielded and unshielded cable constructions.
Level V - cable complies with the requirements in the proposed NEMA Standard for Low-Loss Extended-Frequency Premises Telecommunications Cable. Level V requirements are similar to Category 5 requirements of the EIA/TIA 568A Standard. These requirements apply to both shielded and unshielded cable constructions.

UMAS protocol

unified messaging application protocol Brings together all messaging media in a single interface.

Uni-TE

An application layer communication protocol; This service enables read and write access to variable, program transfers, management of device operating modes, link and device diagnostics and transmission of unsolicited data.

UTP

(*unshielded twisted pair*) One or more cable pairs surrounded by insulation. UTP is commonly used as telephone wire.

V

VijeoLook

PC Base HMI (Human Machine Interface) software from Schneider S.D.

VPN

(*virtual private network*) A network that connects private networks with remote sites using a third party service provider.

VSD

(*variable speed drive*)

W

WAN (*wide area network*) A network using common carrier transmission services for transmission of data over a large geographical area.

WEP (*wired equivalent privacy*) A security protocol for wireless LANs that encrypts data transmitted over radio waves.

workgroup switching Configuration in which a number of users are connected to an Ethernet network via a switch. Switching allows each user to get greater throughput than would be available through a hub.

X

X-Way The addressing mechanism (at the network layer) for the Uni-TE protocol; It enables several Ethway, Ethernet TCP/IP and/or Fipway networks or segments to be interconnected. On TCP/IP Ethernet, X-Way and IP addressing are used in conjunction.

XVM symbols file File extension of exported variables from Unity Pro used by OFS

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